SEVEN CITIES WATER PROJECT
YADKIN RIVER
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GREENSBORO, N. C.	LEXINGTON, N. C.
HIGH POINT, N. C.	THOMASVILLE, N. C.

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TABLE OF CONTENTS

1. LETTER OF TRANSMITTAL—CONCLUSIONS AND RECOMMENDATIONS

February 15, 1957

Seven Cities Water Committee
Attention: Mr. V. B. Higgins, Chairman

Gentlemen:

In compliance with your instructions and in accordance with our contract dated April 16, 1956, we have investigated a Yadkin River water supply to serve the seven cities of Burlington, Greensboro, High Point, Kernersville, Lexington, Thomasville and Winston-Salem. The results of our study are presented in detail in the accompanying report. Our conclusions may be summarized as follows:

1. The total population of the seven cities and their suburbs is expected to increase from approximately 300,000 in 1956, to 450,000 in 1970, and more than 800,000 by the year 2000.

2. The average total water consumption in these cities will increase from 38.6 m.g.d. in 1956 to 70 m.g.d. by 1970, and to 160 m.g.d. by the year 2000. Peak daily requirements will be at least 35 per cent greater.

3. The total capacity of the existing raw-water supply facilities in the seven cities is 54 million gallons a day. This capacity could be increased to approximately 84 million gallons a day by additional works now under construction or likely to be built in the immediate future. Most of the local water supplies could be increased still further by building additional reservoirs, but the potential local development is limited because the streams are small, and their flow will be necessary to carry off sewage and industrial waste from the much greater population anticipated in years to come. Unless major additions are made to the existing local water supplies, the raw-water deficiency will reach 15 m.g.d. by 1980 and nearly 80 m.g.d. by the year 2000.

4. The treated-water capacity must be considerably greater than the average raw-water consumption in order to meet peak daily requirements during dry summer months. The maximum 3-day water demand is expected to increase from 52 m.g.d. in 1956 to 95 m.g.d. by 1970, and to 220 m.g.d. by the year 2000. The existing treated-water capacity, including additional works now under construction or planned, is 70 million gallons per day. If additional facilities are not built, the deficiency in treated water capacity is expected to reach 27 m.g.d. by 1970, 57 m.g.d. by 1980 and 150 m.g.d. by the year 2000.

5. A regional water supply of excellent quality and ample capacity could be developed for the seven cities from the Yadkin River. The water would be taken from an intake near Donnaha just west of Winston-Salem, or at Styers Ferry, frequently considered in the past as a possible site for a hydroelectric plant. The Donnaha site is preferable to Styers Ferry because transmission mains would be shorter and pumping heads lower. Although the immediate cost of building and

operating a regional water supply from the Yadkin River would be greater than augmenting local supplies, the cumulative cost over the years would favor the regional system. Furthermore, the water requirements of this fast growing region, in time, will exceed the potential yield of the local streams. The Yadkin River could be developed successfully to furnish over 500 million gallons per day, and offers the best long range solution.

6. The development of a Yadkin River water supply for the seven cities would involve diversion of water from the Yadkin River basin to the Cape Fear River basin. The diversion would be small in relation to the normal flow of the river. The most serious effect of the diversion would be the reduction of hydroelectric power generation downstream. Our studies show that this loss would not be excessive, and that whatever damages had to be paid would not increase water costs substantially. The proposed water supply system would have such widespread benefits that we believe obstacles as to water rights could be overcome without much difficulty. Construction of the Wilkesboro dam, as proposed by the U. S. Corps of Engineers, with adequate provision for low-stream-flow regulation, would be of great benefit to the seven cities water project, and should be fully endorsed.

7. A raw-water supply from the Yadkin River would consist of an intake dam at Donnaha, a raw-water pumping station, and transmission main to a storage reservoir at Kernersville. Winston-Salem and Kernersville would be served directly from the transmission main. Raw water would be delivered to the other cities through distribution mains from the Kernersville reservoir to the headwaters of the creeks now used as sources of supply by the cities. The first stage of a raw-water project with a capacity of 50 million gallons a day would cost approximately $9,600,000, including allowances for land, engineering, and contingencies, plus $530,000 for distribution mains at Kernersville. The unit cost of raw water delivered to the cities would depend chiefly upon the amount of pumpage.

The cost of furnishing raw water to Burlington, Lexington and Thomasville from a Yadkin River supply as proposed would be excessive, and there is little reason for these cities to participate in such a project. For a modified 4-city raw-water project serving Greensboro, High Point, Kernersville and Winston-Salem, the unit cost of water would range from $144 to $209 per million gallons for a total draft of 10 m.g.d.; $76 to $108 per million gallons for a 20 m.g.d. draft; and $35 to $49 per million gallons for a draft of 50 m.g.d.

8. A filtered-water supply from the same point on the Yadkin River would include an intake dam, raw-water pumping station, filter plant, and transmission mains to a covered reservoir at Kernersville. Winston-Salem and Kernersville would be served directly from the transmission main. The other cities would take water through filtered water mains from the Kernersville reservoir. The construction cost for the first stage including a 30 m.g.d. filter plant is estimated at $16,000,000 plus $7,200,000 for filtered water distribution mains, making a total of $23,200,000. The capacity of the system would be raised to 50 m.g.d. later by increasing the filter plant capacity at an estimated cost of $3,500,000. The cost of filtered water to each city would depend considerably upon the cost of the filtered water mains from Kernersville. For the seven cities, the filtered water cost would range from $273 to $2,148 per million gallons for a total draft of 10 m.g.d.; $150 to $1,087 per million gallons for 20 m.g.d.; and $101 to $519 per million gallons

for a total draft of 50 m.g.d. For Burlington, Lexington and Thomasville, the cost of filtered water would be prohibitive for many years, and we doubt that these three cities should participate fully in a Yadkin River project at this time. Arrangements should be made, if possible, to include them ultimately when local supplies become inadequate.

9. A modified filtered-water project serving only Greensboro, High Point, Kernersville and Winston-Salem would result in water costs to those cities not materially greater than that indicated for the seven-city project.

10. The unit water costs cited above are based upon an allocation of project costs among the participating cities, which would take into account not only the amount of water each city obtained from the Yadkin River project, but also the size of the city as reflected by its total water consumption. The final allocation of costs undoubtedly will require careful study by the Seven Cities Water Committee, and the method proposed may require modification. It is essential, however, that all participating cities contribute substantially to the payment of fixed charges, regardless of the quantity of water taken from the Yadkin River system, because the very existence of a regional water system will benefit each city by assuring an ample water supply for new industries and future population growth.

11. Although a raw water supply from the Yadkin River would cost less than a filtered water system, the filtered water system is much to be preferred because it would relieve the cities of expanding their local works and would provide water service throughout much of the rural area between the cities.

12. It is estimated that from 18 to 24 months would be required for the preparation of plans and specifications ready for the receipt of construction proposals. It is further estimated that approximately three years would be required for construction of the project. It thus appears that approximately five years would be required from the time the preparation of plans and specifications is started until the project could be placed in operation.

It is our recommendation that:

1. A regional filtered water supply from the Yadkin River be provided to meet future water requirements in Greensboro, High Point, Kernersville, Winston-Salem and the rural areas surrounding these cities. The cost of serving Burlington, Lexington and Thomasville from such a supply would be excessive for many years. However, provision should be made, if possible, for extending water service to these cities at such time as their local water resources prove inadequate or uneconomical.

2. Development of the Yadkin River supply be started promptly and pushed vigorously. If this is not done, growing water demands in the cities to be served will force enlargement of existing local supplies at substantial expense and will delay construction of a regional water supply system.

3. The participating cities proceed immediately with the formation of a water authority as permitted under H.B. No. 809, "North Carolina Water and Sewer Authorities Act" of the North Carolina Legislature of 1955.

4. Particular attention be directed to the following major questions:

(a) Feasibility of including the counties as well as the municipalities in the authority.

(b) Methods of financing the works.

(c) Methods of allocating costs among the participants.

(d) Legal steps necessary to establish water rights in the Yadkin River.

5. A copy of this report be sent to the District Engineer, U. S. Corps of Engineers, Charleston, S. C., together with a letter urging that adequate provision for low-stream-flow regulation be included in the Wilkesboro Dam Project.

Respectfully submitted,

PIATT AND DAVIS, Durham, N. C.
By P. D. Davis

WILLIAM C. OLSEN AND ASSOCIATES
Raleigh, N. C.
By C. W. Mengel

HAZEN AND SAWYER, New York City
By Richard Hazen

2. SCOPE OF REPORT

This report describes a regional water supply to serve the seven principal communities of Forsyth, Davidson, Guilford and Alamance Counties in North Carolina and the surrounding territory between the Yadkin River and the Haw River. The limits of the proposed service area are indicated roughly on Exhibit 1. The service area contains approximately 2,000 square miles and a population in excess of 550,000.

Except for a preliminary review of other possibilities, the investigation has been limited to the Yadkin River as the largest and most suitable source of water supply within reasonable distance of the seven cities. A regional water supply might be obtained successfully from the Dan River, but only if a reservoir were built to take care of downstream water users in Virginia and North Carolina during periods of low flow. Even then, the elevation of the Dan River at a suitable intake site is considerably lower than the Yadkin River west of Winston-Salem, and pumping costs would be greater for a Dan River project.

A major water supply could not be developed from the Haw River or the Deep River without the construction of one or more large reservoirs. The dry-weather runoff of these rivers is small, and it would be necessary to store a large percentage of the flood flows in reservoirs. Furthermore, both the Haw River and the Deep River carry off sewage and industrial wastes from much of the region, and the water in these streams must be retained for dilution purposes. Even with the construction of modern sewage and industrial waste treatment plants, the much larger quantities of sewage and wastes in years to come are sure to increase the burden on these rivers. A regional water supply might be taken from the Cape Fear River, perhaps without a storage reservoir if the intake were located far enough downstream. A storage reservoir on the lower Haw River has been proposed by the Corps of Engineers which if not too heavily polluted, probably could be used in part for water snpply purposes. The reservoir would flood much land almost to Chapel Hill and Durham and is not likely to be built soon. In any event the distance from intake to center of water consumption would be at least 60 miles, and the pumping head 800 feet, or more. A Cape Fear water supply for the seven cities project is not attractive.

The ground water resources throughout the area are limited, with most wells yielding less than 30 g.p.m., and cannot be considered for large municipal supplies.

A Yadkin River water supply for the seven cities could be developed in a number of different ways. The less favorable have been eliminated, and attention directed towards the diversion of water from the Yadkin River at either of two sites:

(1) Near Donnaha, northwest of Winston-Salem

(2) At Styers Ferry, almost due west of Winston-Salem

In either case, there would be some legal questions as to the diversion of water from the Yadkin River basin to adjacent river basins. However, in view of the growing need for water supply projects of this type in North Carolina and elsewhere throughout the country, we believe that the legal problems should not be a major obstacle. In a later section of the report, we outline the effects of the proposed diversions on present downstream water users and note also the benefits to be derived from the construction of impounding reservoirs on the Yadkin River as proposed by the U. S. Corps of Engineers.

Two types of project have been considered. Under the first, raw water would be delivered to the several cities as required to supplement their existing local supplies. In this case, the cities would continue to pump water from their reservoirs, to filter their own supplies and to pump the filtered water into their distribution systems.

In the second type of project, Yadkin River water would be pumped to a new filter plant within a few miles of the river, and filtered water would be delivered to the participating cities and intervening areas. The requirements and costs of both plans are stated fully in Section 7 of the report.

Finally, the cost to each city for participating in a regional water supply from the Yadkin River has been estimated. These costs would depend in large measure upon the total water consumption and upon how much each community took. The first step has been to determine the characteristics of the cities to be served, the probable growth in population and water consumption and the potential capacity of existing local water supply works.

3. DESCRIPTION OF SERVICE AREA

The area to be served by the proposed works indicated on Exhibit 1 includes all of Forsyth, Davidson, Guilford and Alamance County. The northwest corner of Randolph County, including the towns of Archdale and Trinity, would probably also come within the service area because this area is quite close to High Point.

The seven cities involved are Burlington, in Alamance County; Greensboro and High Point in Guilford County; Thomasville and Lexington in Davidson County; and Winston-Salem and Kernersville in Forsyth County. The towns of Gibsonville and Elon College are located adjacent to the railroad and highway between Greensboro and Burlington, and these communities would probably be interested in the eventual development.

The area is served by the main line of the Southern Railway, running in a southerly direction to Greensboro and then in a southwesterly direction through High Point, Thomasville, and Lexington. The Greensboro-Goldsboro branch of the Southern serves Burlington and Greensboro, together with the communities between these two cities. A branch of the Southern runs from Greensboro to Winston-Salem, where there is a further branch, one running north and west to Mount Airy, Elkin and North Wilkesboro, and the other southwest to Mocksville, Mooresville, and Charlotte.

High Point is also served by the Carolina and Northwestern Railroad, running south to Asheboro, and the High Point, Thomasville, and Denton Railroad, running southwardly to High Rock. Winston-Salem also is served by a Norfolk & Western branch from Roanoke, Va. and by the Winston-Salem Southbound extending south to and through Lexington and in general down the Yadkin River to Badin and Albemarle.

The entire area is well served by primary highways. U. S. Highways 29 and 70 serve Greensboro, High Point, Lexington, and Thomasville with U. S. 70 extending east from Greensboro to and through Burlington. Winston-Salem and Greensboro are, in addition, served by U. S. Highway 421. U. S. Highway 220 serves Greensboro from the north and south, and U. S. Highway 311 serves High Point and Winston-Salem. Winston-Salem is also served by U. S. Highway 52 and 158. Lexington is served by U. S. 52 and 64. The rural areas are interlaced by state and county highways, most of which are hard surfaced.

The Winston-Salem Airport and the High Point-Greensboro Airport are both served by commercial airlines on regular schedules. The area is served with electric power by the Duke Power Company, and natural gas is available in all of the principal cities.

Industrial development in the past has been primarily textile, consisting of spinning, weaving, and processing, but including relatively small further processing of cloth into manufactured articles for the retail trade. The principal industry in Winston-Salem is cigarette manufacturing. High Point, Lexington, and Thomasville are primarily furniture manufacturing centers, with some textile plants. Textiles are prominent in Burlington, Greensboro and Kernersville. Diversified industry is expanding rapidly in the area, prominent among which are manufacturing plants in the field of electronics, at Burlington, Greensboro and Winston-Salem.

There are numerous desirable industrial sites throughout the entire area where

transportation facilities, either by rail or by highway, are eminently satisfactory. The topography is rolling, and the area well drained by small streams and creeks.

Facilities for higher education are outstanding and well distributed to serve the entire area. A partial list is as follows:

GREENSBORO, N. C.

Woman's College of the University of North Carolina
Greensboro College
Agricultural and Technical College
Bennett College for Women
Immanuel Lutheran College

HIGH POINT, N. C.

High Point College

WINSTON-SALEM, N. C.

Wake Forest College
Salem College and Academy
Winston-Salem Teachers College
Bowman Gray School of Medicine

In addition to the above, the following schools are also located in the service area:

Elon College at Elon College, N. C.
Guilford College at Guilford College, N. C.
Oak Ridge Institute at Oak Ridge, N. C.

The Yadkin River, some twelve miles west of Winston-Salem, and the Dan River, about twenty-five miles north of Greensboro, are the only two large streams in the area. The Dan River at its closest point to Greensboro is approximately at elevation 500, while the Yadkin, west of Winston-Salem at Highway 67, is at elevation 750. Idols Pond on the Yadkin River below Highway 158 is at elevation 670. The Yadkin is the largest stream, and at the near points where it can be most economically reached, is at an elevation some 200 feet higher than the Dan River. The Yadkin River is the more desirable for development.

Satisfactory disposal of industrial wastes and sewage from the area is of considerable importance, even now. Increased development with the attendant larger use of water producing additional industrial wastes and sewage, will materially aggravate this condition. Within the foreseeable future, as the area develops, it probably will be necessary to provide impoundments on some of the smaller drainage areas to augment the dry-weather stream flows to provide additional dilution to aid waste disposal. This might result in converting some of the existing raw-water storage capacity to the regulation of dry-weather stream flows for sewage and waste dilution. In this event the communities involved might be compelled to take their water needs from a more remote water supply developed for the entire area.

The increasing use of water for irrigation is also a problem to be reckoned with. Farmers in the area are continuing to construct small, so-called, farm ponds, the water from which, during dry weather is used for the irrigation of growing crops.

Water used for crop irrigation does not find its way back into the tributary streams, but is dissipated by evaporation and transpiration.

It is anticipated that the agricultural industry in North Carolina will become more fully aware of the value of irrigation and increase its use to the detriment of existing stream flows. However, up to the present time, irrigation developments have been limited to immediately adjacent farm ponds, and there is little or no pumpage from the larger streams. It is possible that existing impounded water supplies of the several cities could be economically applied in part to the irrigation of farm areas as well as to increase the dilution for waste disposal.

Exhibit 2 shows the relative locations of the various communities, the Yadkin River, and the existing water supplies, together with the streams on which they are located. County lines are indicated, and principal highways are shown. Population data for the several communities, including past records and estimated future growth, follows immediately in Section 4 of the report. A brief description of the existing water supply for each community is given in Section 5.

4. POPULATION DATA

Population data are presented herewith in tabular form for each of the seven cities under investigation and for the counties of Forsyth, Davidson, Guilford, and Alamance.

Past population figures are taken from the census records for each decade. Population in 1956 is estimated for each of the cities based either on local census records and estimates, or on an estimated growth at approximately the same rate as past growth. Estimated future populations have been based on annual percentage increases following in general the rate of past growth of the communities.

In estimating future growth no attempt has been made to determine when corporate limit extensions would affect population within corporate limits. The estimated future growth for cities is more on a community basis than on a corporate limit basis, and it has been assumed that corporation lines would be extended from time to time as conditions justified. County land areas taken from Rand-McNally are shown for each county.

In estimating future populations we have used a higher percentage of growth in the early years than in the later years. This would insure a reasonable life for proposed facilities should the actual growth be in line with the estimated growth. Should the growth not equal the estimates, the facilities provided would last somewhat longer.

A summary of present and estimated future population of the seven cities and the four counties is as follows:

Cities	1956	1970	1980	2000
Burlington	28,482	40,240	49,053	72,891
Greensboro	92,000	139,155	169,630	252,064
High Point	45,000	68,066	82,972	123,293
Kernersville	2,860	4,327	5,275	7,838
Lexington	15,738	22,238	27,108	40,282
Thomasville	12,935	18,277	22,280	33,107
Winston-Salem	104,847	158,587	193,318	287,263
Sub-Total	301,862	450,890	549,636	816,738
Counties				
Alamance	80,123	105,679	128,823	191,426
Davidson	70,002	92,329	112,549	167,243
Guilford	228,122	312,840	381,352	566,674
Forsyth	174,485	239,285	291,688	433,437
Total including Cities	552,732	750,133	914,412	1,358,780
% in 7 Cities	54.6	60.1	60.1	60.1

Detailed data for each of the seven cities and each of the four counties, including records of past population growth and estimated future population for each decade, are shown in Appendix A.

5. EXISTING WATER SUPPLY SYSTEMS

We have investigated existing raw-water and treated water facilities of each City. It has been assumed that additional facilities now under construction, or for which construction proposals are about to be received, will be completed and these additions are included as existing facilities. Where raw-water capacity and treated water capacity are not equal, the approximate estimated cost of bringing the raw water and the treated water facilities in balance is indicated. Treated water capacity is based on a nominal rating of 2 gallons per square foot of filter area. A brief description of these facilities is presented herewith. Summarized tabulations follow the descriptions.

BURLINGTON, N. C.

The City of Burlington secures its water from both Stoney Creek and Haw River.

A concrete dam was constructed in 1927 on Stoney Creek near its confluence with Haw River, impounding approximately 400 million gallons. The watershed area above the dam is approximately 104 square miles, and the surface area of the lake, 140 acres. The safe continuous yield is estimated at 3 M.G.D.

On Haw River, between Troxler's Mill and Altamahaw-Ossippee, the City has constructed a low weir and pumping station, together with a twenty inch cast iron transmission main to the headwaters of Buttermilk Creek, a tributary of Stoney Creek. An electric motor driven pump, having a capacity of 4200 gpm has been installed. This installation is used only to augment the Stoney Creek supply during dry periods, and is operated at the beginning of the summer whenever the Stoney Creek reservoir level drops below the spillway crest.

From the Stoney Creek Dam, raw water is pumped to the filtration plant through a 20-inch cast iron line and a 30-inch reinforced concrete line. The capacity of the raw water lines is ample to furnish raw water to the filteration plant in sufficient quantity for the ultimate filter plant development on the present site.

The capacity of the two filtration plants located on the same site is; two M.G.D. for the 1923 plant and, three M.G.D. for the 1949 plant. An addition to the 1949 plant, now under construction, will add two—one million gallon units complete, and three—one million gallon filter units in skeleton form complete except for piping, controls, gravel and sand. Settling basins will have to be provided later for the three skeleton filter units when they are needed. By the summer of 1957, the plants will have a rated capacity of 7 million gallons per day.

Covered clear water ground storage consists of one reservoir having a capacity of five million gallons and, one having a capacity of one-half million gallons.

The City is considering the construction of another dam on Stoney Creek, which will impound 1800 million gallons and will provide a supply, after accounting for evaporation losses, of approximately 7 million gallons per day. This reservoir would be held in reserve to maintain the level of the lower reservoir when needed. The combined storage from the existing and proposed reservoirs should furnish a dependable yield of 10 million gallons per day without pumping from Haw River. This would bring raw water capacity in balance with filter plant capacity and should last until about 1980.

Pertinent elevations above mean sea level are as follows:

Burlington

Stoney Creek Lake Spillway	530
Proposed New Lake Spillway	570
Settling Basins Filter Plant	649
Water Surface Clear Water Reservoir	637
Water Surface Distribution Tanks	798
General Elevation City Area	700

GREENSBORO, N. C.

The Greensboro water supply is taken from Lake Brandt, an impounding reservoir on Reedy Fork and Horse Pen Creeks. The dam is an earth dike with a 143 foot long concrete spillway. The crest of the spillway is about 30 feet above the stream bed. Taking into account the silting which has occurred, the capacity of Lake Brandt is now estimated at 800 million gallons. The reservoir has a drainage area of approximately 70 square miles.

A new 880 million gallon reservoir at the "Hamburg site" on Brush Creek, a tributary of Reedy Fork Creek, has been completed recently. The new reservoir is formed by an earth dam with a 100 foot wide concrete spillway section. The drainage area above this reservoir is about eleven square miles. The Hamburg reservoir will be used to release water to refill Lake Brandt during prolonged dry spells. The capacity of the Hamburg Reservoir is large with respect to the size of the drainage area, but with proper regulation the reservoir should refill every year.

The combined safe yield of Lake Brandt and Hamburg Reservoir is estimated at 15.6 m.g.d. These estimates are based on reasonably long records, including the recent dry years which are among the driest on record.

The Lake Brandt dam and spillway are not reliable and need to be repaired promptly. In the course of this work Lake Brandt can be raised 7 feet economically to increase the storage capacity by 1,400 m.g. This will increase the safe yield of the Brandt Hamburg development to 21.9 m.g.d. A still further increase of 1.5 m.g.d. can be obtained by installing flashboards on the Hamburg Lake spillway. No allowance has been made for the latter increase in this report because it is likely to be offset by occasional demands for water from Cone Mills which do not appear in the water consumption statistics.

The raw-water pumping station at Lake Brandt was built in 1907 and enlarged in 1926. The station contains two diesel-engine-driven pumps of 17 and 12 m.g.d. capacity and a steam-turbine-driven pump with 11 m.g.d. capacity. From the raw-water pumping station, transmission mains extend 5,300 feet to a 19 million gallon raw-water reservoir and continue 31,200 feet to the filtration plant. The mains vary in size from 20 to 36 inches.

The filtration plant is now being expanded from 12 to 20 m.g.d. capacity. The high-lift pumping station is adjacent to the filtration plant and contains three diesel-engine-driven pumps of 20, 11 and 9 m.g.d. capacity and two steam-turbine-driven pumps of 9.5 m.g.d. capacity each.

Clear water storage of 21 million gallons is provided in two uncovered reservoirs, one of 18 and one of 3 million gallon capacity. Limited pipeline capacity

between the reservoir and high-lift pumping station reduces the effective clear well capacity to about 12 million gallons.

Pertinent elevations above mean sea level are as follows:

Greensboro

Lake Brandt Spillway	737
Surface Elevation Raw-Water Reservoir	864
Settling Basins Filter Plant	760
Water Surface Clear Water Reservoir	750
Water Surface Distribution Tank (3)	1005
General Elevation City Area	800

HIGH POINT, N. C.

High Point receives its raw water supply from an impounding reservoir on the Deep River. The dam, built in 1925, is a reinforced concrete structure founded on rock; it is 370 feet long with the crest of the spillway about 45 feet above the stream bed; earth dikes with a concrete core wall extend on both sides of the dam. Taking into account the silting which has occurred, the reservoir impounds approximately 1200 million gallons. The reservoir has a drainage area of approximately 62 square miles and a surface area of 341 acres.

The safe yield of the system is estimated at 10 M.G.D. The large drainage area above the reservoir makes it feasible to increase the safe yield by raising the existing reservoir or by constructing additional storage upstream. Although it has not been fully enforced, the City has agreed to release to downstream owners approximately 10 M.G.D. during such periods as the lake level is not more than 18 inches below the crest of the spillway.

A 30-inch cast-iron transmission main extends 4,000 feet to the raw water pumping station. The pumping station, located adjacent to the Deep River, was built in 1919 and enlarged in 1925. The station contains three electric motor driven pumps with a combined output of 7.75 M.G.D. when operating together and a 3 M. G. D. gasoline engine driven pump. A new 7.5 M.G.D. electric motor driven pump was recently installed.

From the raw-water pumping station, 24-inch and 12-inch cast-iron transmission mains extend approximately 16,600 feet to the filtration plant. The filtration plant was built in 1919 and enlarged in 1951. Some parts of the filter plant require considerable maintenance to restore them to proper operating condition. The nominal capacity of the plant is 7.5 m.g.d., and the plant has been operated above capacity on occasion.

The high-lift pumping station is located adjacent to the filteration plant. This station contains four pumps with a total rated capacity of 16.5 m.g.d. Three of the pumps are electric-motor-driven and one 3.5 m.g.d. pump is gasoline-engine-driven. The maximum capacity of the station is 10 m.g.d. with three pumps operating.

Clear water storage of 3½ million gallons is provided in a single uncovered reservoir.

Pertinent elevations above mean sea level are as follows:

High Point

Lake Spillway	758
Raw-Water Pump Station Floor	711
Settling Basins Filter Plant	925
Water Surface Clear Water Reservoir	913
Water Surface Distribution Tanks	1094 & 1096
General Elevation City Area	880

KERNERSVILLE, N. C.

The Town of Kernersville originally obtained its raw water from a small reservoir on Kerners Creek, with an estimated storage capacity of approximately 6 million gallons and a drainage area of one-half square mile. These works include one electrically-driven 700 g.p.m. pump and one dual driven 750 gpm pump installed in 1951. The water is delivered to the filtration plant through an eight-inch cast-iron pipe approximately one mile long. The original reservoir is now used for emergency supply only.

The present raw water supply was constructed in 1950 and consists of an impounding reservoir on Belews Creek formed by an earth fill dam with a concrete lined spillway. The reservoir covers a surface area of 55 acres and has an estimated capacity of 115 million gallons. The drainage area tributary to the lake is 3.3 square miles. The maximum continuous yield of this supply, based on the dry year of 1933, is approximately 0.75 M.G.D. The decrease in yield, due to silting, will be minor due to the relatively small water shed The existing raw water capacity should suffice until about 1970.

The pumping facilities at the new lake consist of two 700 gpm pumps. Static head at the pump is 200 feet and the total head with one pump running is 270 feet. The water is delivered to the filtration plant through a ten-inch cement asbestos pipe 11,000 feet long, tied to 800 feet of eight-inch cast iron force main from the old lake at the filter plant end. Only one pump is operated at a time.

The filter plant was constructed in 1927 with a nominal capacity of one M.G.D., and is in need of reconditioning. Average daily pumpage from the plant during June of this year was estimated by the operator at 620,000 gallons per day. There are no meter records. Covered clear water ground storage is 250,000 gallons.

The raw water supply on Belews Creek can be increased by raising the dam and increasing the storage capacity of the reservoir. The maximum development of this site is approximately 1.5 M.G.D. continuous yield and would require 350 million gallons storage. The earth dam would have to be raised and the east abutment, which was used as a borrow pit for part of the original dam, would have to be refilled. Existing pumps could be used. The pump station would have to be revised and a section of the force main replaced. The total cost of increasing the yield of raw water from the lake, as described above, would be approximately $160,000. This increased yield would be sufficient to supply the expected needs of Kernersville until 1980.

A report dated June, 1956 by W. K. Dickson & Co., recommends modernizing the existing plant without increasing its capacity at an estimated cost of $92,000. An additional one-half M.G.D. capacity to balance the additional raw water supply is estimated to cost approximately $125,000.

Kernersville

Pertinent elevations above mean sea level are as follows:

New Lake Spillway Now	817
New Lake Spillway if Raised	830
Settling Basin Filter Plant	1011
Water Surface Clear Water Reservoir	1000
Water Surface Distribution Tank	1161
General Elevation of City Area	1020

LEXINGTON, N. C.

Lexington secures raw water from two sources; one, on Abbott's Creek without impoundment and, the other on Leonard's Creek where an impounding reservoir was constructed in the late thirties. On Abbott's Creek, near the water filtration plant, a low weir provides catchment facilities for the regular creek flow, but there is no storage as such.

The reservoir on Leonard's Creek covers an area of 67 acres and impounds 150 million gallons of water. The dam is of earth and concrete. Water is delivered to the filtration plant by pumping through a twelve inch cast iron line. The watershed area above the dam is small, and further development of this watershed does not appear desirable.

During recent years, notably 1953 and 1954, the flow in Abbott's Creek dropped practically to zero and the entire supply had to be secured from the Leonard's Creek reservoir. During such periods the yield from both sources was less than two and one-half million gallons per day.

Additional raw water storage is now being provided by the construction, jointly by the Cities of Lexington and Thomasville, of a reservoir on Abbott's Creek, between the Thomasville intake and the Lexington intake. Spillway level of this reservoir will be at elevation 685 and, at such level the reservoir capacity will be approximately 2,000 million gallons. Construction should be completed by July, 1957.

A report by L. E. Wooten and Company, Consulting Engineer states, "It is estimated that after evaporation and silting, by 1985 the dependable supply will be about 12,200,000 gallons per day." The same report gives the drainage area above the dam as 70 square miles.

The existing filtration plant was originally constructed between 1920 and 1925 and consisted of four one-half M.G.D. filter units. During the year 1948 additions were constructed, consisting of four three-quarter M.G.D. capacity filters, two of which were equipped. The remaining two are not yet equipped.

The present effective capacity of the plant is 3.5 M.G.D. By equipping the two other filter units, the capacity can economically be increased to 5.0 million gallons per day. This should care for Lexington's needs until about 1975. Clear water ground storage of one million gallons is provided in a single covered reservoir.

Pertinent elevations above mean sea level are as follows:

Lexington

Spillway Lake now under construction	685
Settling Basins Filter Plant	675

Water Surface Clear Water Reservoir	664
Water Surface Distribution Tank	916
General Elevation City Area	780

THOMASVILLE, N. C.

Thomasville secures its raw water from Abbotts Creek, using the regular flow of the creek with a low weir, providing only sufficient storage height to cover the intake pipe. The elevation of the creek bottom at the intake is 670. This source of supply has been used since 1925, and except for 1953, 1954, and 1956, has been ample. Water is pumped through two cast-iron pipe lines, one 12" and one 16", to the filtration plant, a distance of approximately 4½ miles.

Thomasville and Lexington have under construction a combined raw-water supply, described previously in connection with the water supply for Lexington. It should be noted that, for the 2,000 million gallon storage capacity in the proposed reservoir, 1400 million gallons will be available above the elevation of the Thomasville intake.

A new raw-water pumping station now under construction will be equipped with two pumps, having capacities of 2500 gpm and 1500 gpm. The pumping station floor elevation is 675.

The filtration plant capacity for Thomasville is three million gallons per day, consisting of six one-half M.G.D. capacity filter units. Clear water ground storage of 1¼ million gallons is provided in two reservoirs, one of one million gallon capacity and one of one-quarter million gallon capacity, both of which are covered. Encroachments of highways and other facilities are such that the existing plant cannot be enlarged further. Elevated storage consists of a one million gallon capacity tank. The existing plant should last until about 1970.

Thomasville

Pertinent elevations above mean sea level are as follows:

Spillway Lake now under construction	685
Settling Basins Filter Plant	860
Water Surface Clear Water Reservoir	849
Water Surface Distribution Tank	998
General Elevation City Area	800

WINSTON-SALEM, N. C.

Winston-Salem uses two sources of raw water. The source first developed is on Salem Creek and includes an impounding reservoir constructed in 1919. The dam is of concrete and was approximately 25 feet high when constructed. It has been raised 3 feet, giving the lake a total estimated original storage capacity of 1300 million gallons. This original storage has been reduced approximately 140 million gallons by silting, leaving a present net of 1160 million gallons. The lake covers a surface area of 325 acres and has a continuous yield, based on the dry year 1933, of nine million gallons per day. This is not the maximum development of the twenty-five square mile watershed, but further development does not appear to be economically sound. The raw water flows by gravity through a 48" steel main from the impounding reservoir to the City's filter plant.

The other source is the Yadkin River, developed in 1950 when additional filter plant capacity was provided. This development consists of an electrically operated pump station at the Yadkin River with an intake constructed in the small lake formed by Idols Dam, owned by Duke Power Company. The location of this pumping plant is approximately three miles downstream from U. S. Highway 158 crossing and immediately below the Southern Railway line to Mocksville. By agreement with Duke Power Company, the City of Winston-Salem has the right to take up to forty M.G.D. from this source. The pumping station houses two vertical motor driven pumps, each capable of delivering ten M.G.D. to the City's filtration plant. Motors are synchronous 600 h.p. Static head under present operating conditions is 221 feet and pumping head with both pumps running is 244 feet. There is no provision in the pumping station for additional pumps.

The water is delivered through a single 36-inch reinforced concrete force main 16,000 feet long, to a standpipe at the high point from which it flows by gravity through 58,000 feet of 36-inch reinforced concrete line to the filter plant.

With certain piping revisions at the filtration plant, the combined continuous yield of twenty-nine M.G.D. from both sources of raw-water supply could be used. The estimated cost to make these revisions is $100,000. This rate of consumption will be reached about 1975. An additional pipeline to the Yadkin River and a pumping station to use the maximum amount of water covered by the agreement with Duke Power Company would further increase the raw-water supply to a total of 49 M.G.D. The cost of this additional pipeline and pumping station at present day prices would be approximately $2,900,000.

The filtration plant has a nominal capacity of 20 M.G.D. By operating the newer units at above normal rates a maximum of approximately 23 M.G.D. can be treated. Clear water ground storage of 6 million gallons is provided in three circular uncovered reinforced concrete reservoirs. It is questionable whether the maximum filter plant capacity will last much beyond 1960. The maximum present pumping capacity is 28 M.G.D. The maximum daily use in June of 1956 reached 20.73 M.G.D. and the average of the three maximum consecutive days was 19.6 M.G.D. The peak rate of use during maximum days required the operation of all pumps. Additional filter capacity of 10 M.G.D. can be added, either at the present site or a new site, at an approximate cost of $225,000 per million gallons, totalling $2,250,000. This added capacity will balance the existing maximum raw water capacity and should supply the anticipated needs under normal growth until about 1970.

Pertinent elevations above mean sea level are as follows:

Winston-Salem

Salem Lake Spillway	796
Idols Dam Spillway	670
Overflow Surge Tank 36" Raw Water Line	905
Settling Basins Filter Plant	781
Water Surface Clear Water Reservoir	771
Water Surface Ninth St. L. L. Distribution Tank	1060
Water Surface Reynolda Rd. H. L. Distribution Tank	1095
General Elevation of City Area	900 plus

The capacities of the existing raw-water and filtered-water facilities at each of the seven cities are summarized in the two tables following. The first column shows the capacities of works now available. The "maximum" capacity is the limit if the works now under construction, authorized, or easily accomplished, are built. It includes, for example, the additional yield of the Greensboro supply if Lake Brandt is repaired and raised, the available filter capacity at Lexington if the two remaining filter boxes are equipped, etc. Except for a new reservoir at Burlington, it does not include major additions to supply and treatment works that may be authorized in the future.

As shown by these tables, the developed raw-water systems have a capacity of 54.0 m.g.d., which may be readily increased to 83.9 m.g.d. The present filtered water capacity is 54 m.g.d. With additions now underway, or easily accomplished, the filtered-water capacity would be 69.5 m.g.d.

CAPACITY OF EXISTING RAW WATER FACILITIES
ANNUAL AVERAGE IN M.G.D.

	Existing Development	Maximum	Cost to Develop Maximum
Burlington (1)	4.6	10.0	$1,050,000
Greensboro (2)	15.6	21.9	1,500,000
High Point (3)	10.0	10.0	See Note
Kernersville	.8	.8	———
Lexington	2.0	12.2	Combined Supply
Thomasville	1.0		Under Const.
Winston-Salen (4)	20.0	29.0	$100,000
Total	54.0	83.9	

(1). 3 M.G.D. from existing storage. The added 1.6 M.G.D. represents the minimum additional supply available from Haw River over the lowest 30 day flow on record. By pumping from Haw River as soon as water in the Stoney Creek Reservoir falls below the crest of the dam, a supply of at least 7 M.G.D. would be available. New lake proposed will add 7 M.G.D. at estimated cost of $1,050,000.

(2) Can provide additional 6.3 M.G.D. by repairing and raising Lake Brandt at estimated cost of $1,500,000.

(3) Capacity of existing supply 10 M.G.D. City has agreed by letter to discharge 10 M.G.D. downstream during such times as lake is not more than 18 inches below spillway. This should not seriously affect yield.

(4) Can revamp raw water piping at the filter plant site so as to use the combined supply of 29 M.G.D. from both Salem Lake and Yadkin River at estimated cost of $100,000.

CAPACITY OF EXISTING TREATED WATER FACILITIES
ANNUAL AVERAGE IN M.G.D.

	Existing Capacity	Maximum	Cost to Develop Maximum
Burlington (1)......	7.0	10.0	$200,000
Greensboro.........	12.0	20.0	Under Construction
High Point (2)......	7.5	7.5	See Note
Kernersville (3).....	1.0	1.0	$92,000
Lexington (4).......	3.5	5.0	$50,000
Thomasville (5).....	3.0	3.0	See Note
Winston-Salem (6)...	20.0	23.0	See Note
Total..........	54.0	69.5	

(1) New facilities under construction will bring capacity to 7 M.G.D. in 1957. Can equip 3 additional 1 M.G.D. filters and construct settling basins to increase capacity to 10 M.G.D. at estimated cost of $200,000.

(2) Existing plant barely sufficient for present needs. Can increase capacity only by building additional plant.

(3) Physical condition of existing plant poor. Can revamp for estimated cost of $92,000.

(4) Can equip 2 additional ¾ M.G.D. filters at an estimated cost of $50,000.

(5) Can increase only by building new plant on new site. Existing facilities estimated to last until about 1975.

(6) Indicated increase by operating existing units above normal rate. Can add new capacity at estimated cost of $225,000 per million gallons either at existing site or on new site nearer raw-water supply. Existing site limited.

6. PAST WATER CONSUMPTION AND ESTIMATED FUTURE NEEDS

Following hereinafter in Appendix B are tabulations of past water consumption for each of the various cities and their estimated future needs, based on estimated future population and per capita use. The existing per capita daily use of water in the several communities varies considerably as indicated in the following summary of population and water consumption for 1956.

SUMMARY OF POPULATION AND WATER CONSUMPTION—1956

		Water Consumption Per Day				
		Average Annual		Average of Max. 3 Days		
	Pop.	Total	Per Cap. Daily	Total	Per Cap. Daily	% Avg. Annual
Burlington	28.5	4.7	165	6.0	210	128
Greensboro	92.0	10.0	109	13.5	147	135
High Point	45.0	5.4	120	7.3	162	135
Kernersville	2.9	0.6	207	0.7	240	117
Lexington	15.7	2.0	127	3.0	191	150
Thomasville	12.9	1.3	101	1.8	139	138
Winston-Salem	104.8	14.6	140	19.6	187	134
Totals	301.8	38.6	128	51.9	172	135

Population in thousands to nearest tenth.
Total water consumption in M.G.D. to nearest tenth.
Average consumption per cap. per day for Max. 3 days is equivalent to 135% of average annual daily use.

The variation in per capita consumption is due to the amount and type of industrial development within the particular communities and to the further fact that most of the cities occasionally have been short of water over a considerable number of years. Privately owned systems furnish water in some of the communities, particularly in Greensboro, where Cone Mills Corporation has its own system. The production of private systems is not included in our figures.

The average annual per capita daily use of water for all of the communities during 1956 was 128 gallons. This includes water furnished by the communities to industry, but does not include private supplies. Burlington used water at a per capita daily rate of 163 gallons, and Kernersville at a rate of 200 gallons. The Kernersville system is not well metered, and there is some question as to the accuracy of the Kernersville figure.

It is unlikely that future needs of the separate communities will be equal on a per capita basis, but in estimating over-all needs, we have used the same unit figures for each individual community to arrive at the total expected need for the future. The water consumption estimates include allowances for growth in fringe areas around each city, but no estimate has been prepared for probable needs in county areas presently remote from any municipal water supply. These needs could gradually develop into a sizeable quantity.

In estimating future water needs it has been assumed that the average daily

use per capita, including that used by industry, will gradually increase to 200 gallons in the year 2000. Except for Burlington and Kernersville, we have used for estimating future needs, 140 gallons for 1960, 155 for 1970, 170 for 1980, 185 for 1990, and 200 for 2000.

These per capita figures have been applied to the estimated future population in each of the seven cities to determine the total water needs in 1970, 1980 and 2000. The average and 3-day maximum demands are shown in the table following:

ESTIMATED FUTURE POPULATION AND WATER CONSUMPTION

		Estimated Water Needs Per Day	
Year 1970	**Population**	**Avg. Annual**	**Max. 3 Days**
Burlington	40.2	6.70	9.05
Greensboro	139.2	21.57	29.12
High Point	68.1	10.55	14.24
Kernersville	4.3	.86	1.16
Lexington	22.2	3.45	4.66
Thomasville	18.3	2.83	3.82
Winston-Salem	158.6	24.58	33.18
Total	450.9	70.54	95.23
Year 1980			
Burlington	49.1	8.34	11.26
Greensboro	169.6	28.84	38.93
High Point	83.0	14.11	19.05
Kernersville	5.3	1.05	1.41
Lexington	27.1	4.61	6.22
Thomasville	22.3	3.79	5.12
Winston-Salem	193.3	32.86	44.36
Total	549.7	93.60	126.35
Year 2000			
Burlington	72.9	14.58	19.68
Greensboro	252.0	50.41	68.05
High Point	123.3	24.66	33.29
Kernersville	7.8	1.66	2.24
Lexington	40.3	8.06	10.88
Thomasville	33.1	6.62	8.94
Winston-Salem	287.3	57.45	77.56
Total	816.7	163.44	220.64

Population in Thousands. Water Consumption in million gallons per day based on average use in year 1970 of 155 gallons per capita, in 1980 of 170 gallons, and in 2000 of 200 gallons. Maximum 3 days calculated at 135% of average annual daily use.

For the seven cities project, the raw water capacity has been calculated on the basis of the average daily consumption because peak drafts in excess of the average could be met temporarily from existing reservoirs. Treated water needs have been estimated as the average of the three highest daily demands in any year. This is designated as the "3 Day Maximum" in this report. No provision would be made for peak hourly drafts or fire flows in the Yadkin River project. These would be met from local storage reservoirs and elevated tanks, as at the present time.

On the basis of past experience the total 3 day maximum demand is estimated at 135 per cent of the average demand. In many American cities the ratio of peak to average demands has jumped spectacularly in recent years, and allowances of 150 per cent to 200 per cent are common. The 135 per cent applied in this report may prove to be inadequate. However, the relatively large industrial water use tends to be uniform throughout the year and moderates the effects of peaks in domestic consumption during summer months, particularly those caused by lawn sprinkling. The marked increase in the per capita water consumption forecast for the seven cities is predicated on not only greater domestic use, but also substantial industrial development.

As an indication of current thinking on average and maximum per capita water use throughout the United States, we have included in Appendix C an estimate of future use by water works superintendents, from the December, 1956 issue of Public Works Magazine.

In determining the capacity of works to be built, it is assumed that, at least for the present, each of the seven cities would continue to operate the facilities it now has. As the communities grow, and the need for additional water increases, it is expected that the increase would come from the Yadkin River regional supply. An existing supply may be abandoned later and the entire water needs for that particular commuinty drawn from the regional development. The trend in this direction, we believe, can be determined promptly enough to increase the proposed facilities from time to time as may be needed. In the case of a treated water supply for the area, it is anticipated that considerable use of water would develop along the transmission mains in presently rural parts of the counties. This would help carry the over-all cost of the development and its operation.

The tabulation next following shows the needed additions to both raw water supplies and filter plant capacity provided all existing facilities are retained and operated at their maximum. Burlington will need no additional filter plant capacity until about 1980, and if the additional proposed raw water supply is constructed, will need no further raw water additions until after 1980. Lexington will need no additional treated water capacity until after 1970 and neither Lexington nor Thomasville will need raw water until after 1980, and only slight additions by 2000. Greensboro, High Point and Winston-Salem will need no raw water until after 1970. High Point needs additional filter plant capacity almost immediately; Greensboro and Winston-Salem perhaps by 1965. Kernersville will need slight additions to both their raw water supply and filtered water capacity by 1970.

INDIVIDUAL EXISTING CAPACITY IN RELATION TO FUTURE NEEDS

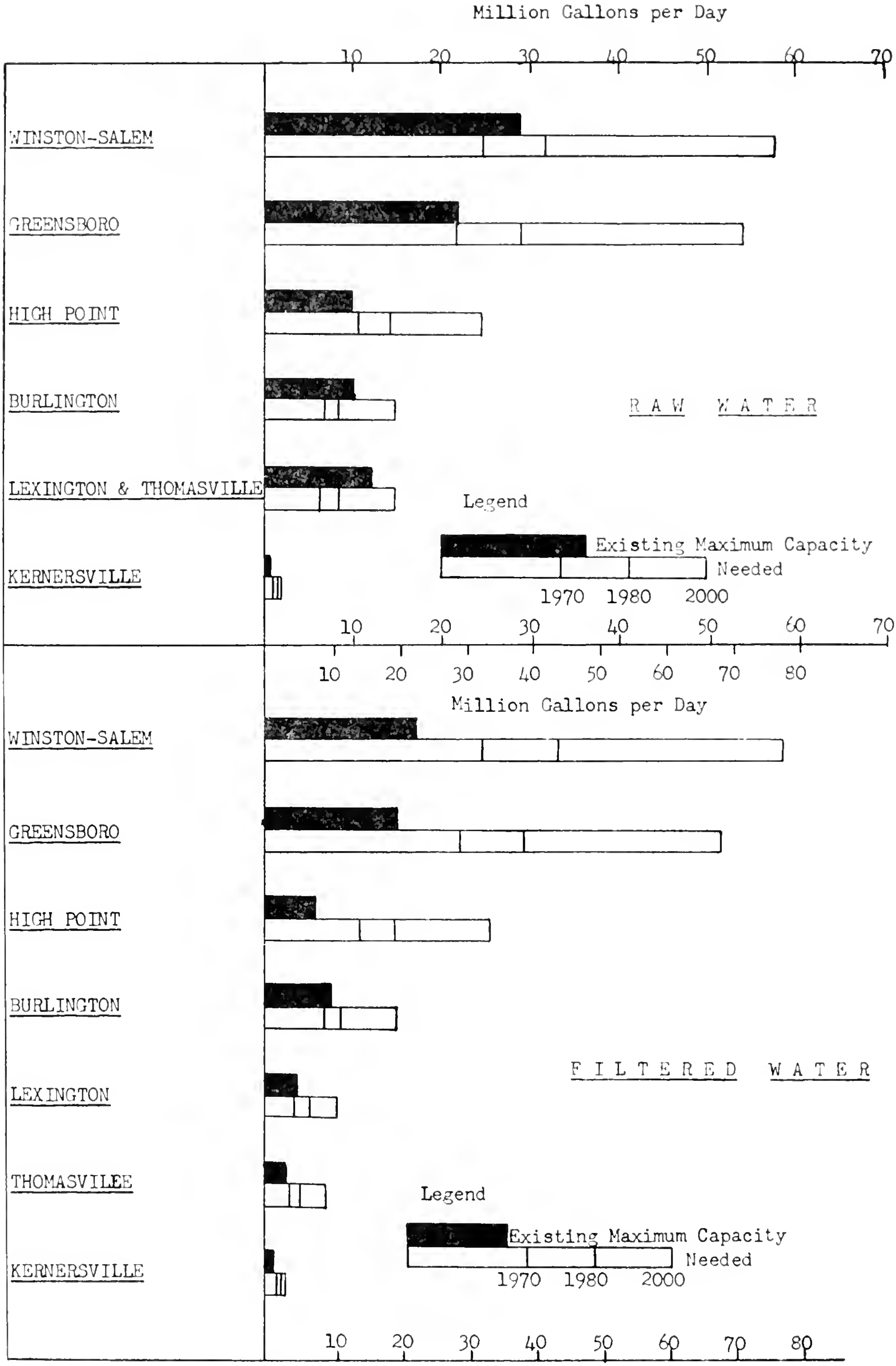
RAW WATER FOR AVERAGE ANNUAL DAY

	Existg. Max. Capacity	Needed 1970	Additions Required	Needed 1980	Additions Required	Needed 2000	Additions Required
Burlington	10.0	6.70	0.00	8.34	0.00	14.58	4.58
Greensboro	21.9	21.57	.00	28.84	6.94	50.41	28.51
High Point	10.0	10.55	.55	14.11	4.11	24.66	14.66
Kernersville	.8	.86	.06	1.05	.25	1.66	.86
Lexington } Thomasville }	12.2	3.45	0.00	4.61	0.00	8.06	2.48
Thomasville		2.83	0.00	3.79	0.00	6.62	
Winston-Salem	29.0	24.58	0.00	32.86	3.86	57.45	28.45
Total	83.9	70.54	.61	93.60	15.16	163.44	79.54

TREATED WATER FOR MAXIMUM 3 DAYS

	Existg. Max. Capacity	Needed 1970	Additions Required	Needed 1980	Additions Required	Needed 2000	Additions Required
Burlington	10.0	9.05	0.00	11.26	1.26	19.68	9.68
Greensboro	20.0	29.12	9.12	38.93	18.93	68.05	48.05
High Point	7.5	14.24	6.74	19.05	11.55	33.29	25.79
Kernersville	1.0	1.16	.16	1.41	.41	2.24	1.24
Lexington	5.0	4.66	0.00	6.22	1.22	10.88	5.88
Thomasville	3.0	3.82	.82	5.12	2.12	8.94	5.94
Winston-Salem	23.0	33.18	10.18	44.35	21.36	77.56	54.56
Total	69.5	95.23	27.02	126.35	56.85	220.64	151.14

Quantities in Million Gallons per Day


Million Gallons per Day
10 20 30 40 50 60 70
WINSTON-SALEM
GREENSBORO
HIGH POINT
BURLINGTON
LEXINGTON & THOMASVILLE
KERNERSVILLE
R A W W A T E R
Legend
Existing Maximum Capacity
Needed
1970 1980 2000
10 20 30 40 50 60 70
10 20 30 40 50 60 70 80
Million Gallons per Day
WINSTON-SALEM
GREENSBORO
HIGH POINT
BURLINGTON
LEXINGTON
THOMASVILEE
KERNERSVILLE
F I L T E R E D W A T E R
Legend
Existing Maximum Capacity
Needed
1970 1980 2000
10 20 30 40 50 60 70 80

Attention is directed again to the fact that the total water requirements in nearly all of communities may be greater than indicated because of the necessity for dilution water to carry off sewage and industrial wastes. The requirements at each city will depend upon the size of the receiving stream and the standards imposed by the North Carolina Stream Sanitation Committee. However, it is obvious that the natural dry-weather flows of Muddy Creek ultimately will be small compared to the total waste from Winston-Salem, lower Reedy Fork Creek will be small for Greensboro, and the head waters of Rich Fork Creek and Deep River small for High Point. An analysis of the situation at Greensboro indicates that it may be necessary to divert as much as 30 or 40 per cent of the water supply capacity on Reedy Fork Creek for waste dilution, and that because of this Greensboro ultimately must look to one of the larger, more distant rivers as its source of water supply. The effect of waste disposal on other municipal water supplies may be more or less severe than at Greensboro, but if the streams are to be cleaned up and kept free from nuisance, some regulation of low flows seems inevitable.

Water consumption data for each of the seven cities are set forth in Appendix B.

7. YADKIN RIVER PROJECT

General Considerations

The capacity of works to be built and the average pumping from the Yadkin River to supplement existing local supplies will be the same regardless of intake location or route followed by the pipeline to serve the seven cities. Likewise, the potential intake sites are close enough together that the effects of pumpage on Yadkin River flows and the effects of diverting water from the Yadkin River basin will be substantially the same whichever site were selected. Before discussing the several possible projects in detail, some of the factors applicable to all will be reviewed.

Quantity of Water to be Pumped from the Yadkin River

As noted in the previous section of the report, the over-all water supply deficiencies in the seven cities, if local works are not increased beyond improvements now underway or easily accomplished, are estimated as follows:

Estimated Deficiencies in Existing Supplies—m.g.d.

	1970	1980	2000
Raw Water Capacity (average daily)	0.6	15.2	79.5
Treated Water Capacity (3-day maximum) . .	27.0	56.9	151.1

The local works are more nearly adequate as to source of supply than filter plant capacity. This is natural, since it is unusual for a community to build filter plant capacity beyond the available supply. Although detailed figures are used in the tables to assure accurate accounting of demands and existing capacity, the estimates are necessarily approximate. They are adequate for determining what capacity should be provided in the Yadkin River system, particularly in the first step of a proposed stage development.

The amount of water taken from the Yadkin River through the proposed seven cities supply would depend not only upon how fast the cities grow, but also upon whether the Yadkin River supply is a raw-water system or a filtered-water system. If a filtered-water system is built, the total pumpage from the Yadkin River will be substantially greater than if the river is used only to furnish raw water. The reason for this is that, although the local water works are designed for dry-weather conditions, much of the time the water available in the streams and reservoirs is substantially greater than the estimated safe dry-weather yield. As long as the municipal water works facilities include adequate transmission and filter capacity, the wet-weather flows could be used fully, and pumping from the Yadkin River would be required only during periods of drought. On the other hand, if a filtered-water supply were obtained from the Yadkin River, the local filter plants would not be enlarged, and the entire deficiency would be met by pumping water from the Yadkin River through the filter plant, probably 365 days in a year.

An exact determination of the quantity of raw water needed from the Yadkin River to increase the over-all output of the seven cities systems by a specified amount would require a hydrological analysis of each local source of supply and correlation with the raw-water transmission and filter plant capacity. Such a study is not justified because of the many variables involved and because changes in water

consumption forecasts for each city would affect the result. However, by comparing the average long-term yields with dry-year yields, and drawing on a study made in connection with the Greensboro demands, we estimate that on the average the raw-water requirements from the Yadkin River would be about one-half the filtered-water requirements to take care of the same total demand. In other words, to meet a deficiency of 40 m.g.d. in filtered water demands, approximately 20 m.g.d. of raw water would be needed on the average from the Yadkin River to supplement local flows. In this case, however, each city would have to build additional transmission and filter capacity to meet its total requirements. Furthermore, the capacity of the raw-water system would have to equal the average filtered water demands because in extremely dry weather, the yield of the local supplies would be much less than average. The details of the Greensboro analysis are shown in Appendix C. In estimating raw-water requirements, the amount pumped from the Yadkin River has been increased by 25 per cent to allow for evaporation and losses while flowing down the creeks to the existing reservoirs, and for filter wash water.

The capacity of the Yadkin River works necessary to make up future deficiencies in municipal supplies is shown graphically in Exhibit 3. The upper portion pertains to a raw-water supply; the lower to a treated-water supply. The two projects are described below by reference to this exhibit.

Raw-Water Supply—Exhibit 3-A

In this project it is assumed that raw water would be pumped from the Yadkin River to the headwaters of the several local water supply systems in order to refill existing reservoirs. The Yadkin River water would be pumped only when necessary, and during wet seasons, when the local runoff exceeded water demands, the local sources would be used exclusively. It is assumed that the pumping stations, transmission mains, and filter plants for each city would be enlarged as necessary to meet seasonal and peak daily water demands. Under this arrangement raw water would be pumped from the Yadkin River at a fairly steady rate, ordinarily not exceeding the average requirements from the river in a dry year. The local reservoirs would be kept reasonably full at all times, and the peak demands would be met from these reservoirs.

In Exhibit 3-A the total raw-water demands, as determined in Section 5 of the report, are shown by the upper solid line extending from 70.5 m.g.d. in 1970 to 163. m.g.d. in the year 2000. The lower line, extending from 69.9 m.g.d. in 1970 to 83.2 m.g.d. in 2000, shows the raw-water capacity of the existing local supplies, with additions now contemplated or easily accomplished. The local capacity is not shown at 83.2 m.g.d. throughout the period simply because the excess raw-water capacity at Burlington, Lexington, Thomasville and Winston-Salem would not be available for use in the other cities during the early years of the project. Thus, until the raw-water demands have reached the local capacity in each community, not all of the 83.2 m.g.d. capacity could be utilized.

The difference between the total demand and local supply lines represents the capacity to be provided in the Yadkin River project. As noted earlier, this has been increased by 25 per cent to allow for water losses.

It should be noted that Exhibit 3 shows the raw-water *capacity* needed. The amount of water actually pumped from the Yadkin River would equal the capacity in a dry year. In a wet year the pumpage would be much less. In general, North

Carolina impounded water supplies yield 30 to 50 per cent more water during the average year than they do in an extremely dry year. Thus, the local supplies might furnish 100 to 110 m.g.d. instead of the 70 to 83 m.g.d. capacity shown, and the average pumpage from the Yadkin River over a period of years would be proportionately less.

Filtered-Water Supply—Exhibit 3-B

In this plan it is assumed that Yadkin River water would be filtered near the intake and pumped directly to the distribution systems of the seven cities. It is also assumed that the local raw-water pumping stations, transmission mains and filter plants would not be enlarged and that peak demand deficiencies would have to be met from the Yadkin River. The 3-day maximum water demand is shown by the solid line in Exhibit No. 3-B ranging from 52 m.g.d. in 1956 to 95 m.g.d. in 1970 and 221 m.g.d. in the year 2000. It is assumed that the capacity of the existing filter plants would remain substantially as at present, as shown by the horizontal line at 69.5 m.g.d. The difference between the 3-day maximum demand and 69.5 m.g.d. represents the capacity that must be provided in the new Yadkin River system.

The capacity of the works would be based on the 3-day maximum demands, which have been taken at 35 per cent more than the average. The average quantity of water to be pumped from the Yadkin River would be considerably less than the peak capacity required. The average total filtered-water requirements are estimated to range from 39 m.g.d. in 1956 to 70 m.g.d. in 1970 and 163 m.g.d. in the year 2000.

The capacities to be provided in a Yadkin River water supply project and the average pumpages are summarized in the table following:

Year	Total Average Water Consumption m.g.d.	Raw Water Required Capacity* m.g.d.	Raw Water Aver. Annual Pumpage** m.g.d.	Filtered Water Required Capacity m.g.d.	Filtered Water Aver. Annual Pumpage m.g.d.
1960		.0	.0	.0	
1970	70.5	0.8	0.5	27.0	20
1980	93.6	19.0	11.9	56.9	42
2000	163.4	100.0	62.5	151.1	112

*Capacities developed in Section 5, plus 25% for losses.

**One-half of deficiency (= capacity) plus 25% for losses.

The most significant conclusions to be drawn from these data are as follows:

1. If the seven cities built a filtered-water project in lieu of additions to their own plants, the new Yadkin River water supply would be needed by 1965. If a raw-water project were planned, construction could be postponed for several years.

2. For a total average water demand of 94 m.g.d. (estimated 1980) in the seven cities, a project to furnish filtered water to the seven cities would need to be three times as large as a raw-water project. By the year 2000, when local supplies would be less significant, the ratio would drop to about 1½.

3. For a total average water demand of 94 m.g.d. (estimated 1980) in the seven cities, a project to furnish filtered water would require on the average about three times as much pumpage as a raw-water project. In later years this ratio would drop to about 1.3.

4. Even with a filtered-water project, the average pumpage from the Yadkin River is estimated at only 20 m.g.d. in 1970, 42 m.g.d. in 1980, and 112 m.g.d in the year 2000. As discussed in the next section of the report, these flows are small in relation to the stream flows of the Yadkin River.

Capacity to be Provided

In order to keep within reasonable limits the initial construction cost of the project and the unit cost of water, the Yadkin River water supply must be built in stages. The first stage should take care of estimated requirements for at least 15 or 20 years. Additions could be built later as needed to meet growing water demands. The pumping stations and filter plant could be enlarged economically from time to time by installing additional units, as long as the original works were designed with this in mind.

Stage development of long pipelines is more difficult. If a pipeline it too small, its capacity may be increased within limits by the addition of booster pumping stations, but a major increase in load requires the laying of a parallel line. This is likely to cost fully as much as the original pipeline. On the other hand, it costs relatively little to provide excess capacity in the beginning by using a somewhat larger diameter pipe. This procedure has the advantage in that it reduces friction loss and pumping costs during the early stages of the project. The pumping head from the Yadkin River to the seven cities is high in any event, and the use of a fairly large pipeline is indicated.

The project studies and cost estimates are based upon a 54-inch pipeline between the Yadkin River and Winston-Salem and a 48-inch line beyond Winston-Salem. These lines would provide a capacity of 50 m.g.d. to Winston-Salem, and 33 m.g.d. beyond that point. It is assumed that about one-third of the total water from the Yadkin River would be used in the vicinity of Winston-Salem, and that the balance would be transmitted to High Point, Greensboro and the other cities.

The same size pipeline is proposed for raw-water and filtered-water systems, although the quantities of raw water would be substantially less than filtered-water quantities for a number of years. The large-diameter line should be used because even if a raw-water system were built initially, it probably would be converted ultimately to a filtered water system. The proposed pipeline should be adequate for a filtered-water supply until 1980. If a raw-water supply is built, the transmission mains should be adequate for ten years longer.

Relation of Pumpage to Stream Flows

The drainage area of the Yadkin River above the U. S. Geological Survey gage at Yadkin College is 2,280 square miles. The discharge of the river since the gage was established in 1928 has averaged 2,880 c.f.s., or 1,860 m.g.d. The minimum daily flow of 330 c.f.s., or 214 m.g.d., was recorded on October 9, 1954, and again on September 23, 1956. The maximum flood flow of record was 80,200 c.f.s., in August, 1940. A higher discharge of 86,600 c.f.s. in July, 1916, has been estimated from flood marks.

The critical flows at Donnaha and Styers Ferry have been calculated from the Yadkin College records on the basis of drainage areas as follows:

	Yadkin College	Styers Ferry	Donnaha
Drainage Area—s.m.	2,280	1,870	1,620
Mean Discharge—m.g.d.	1,860	1,530	1,320
Minimum Daily Discharge—m.g.d.	214	175	152

The annual flows of the Yadkin River at Styers Ferry are plotted in Exhibit 4.

The daily flows at Styers Ferry during the calendar year 1954 are plotted in Exhibit 5 to illustrate the variations in flow. The year 1954 was selected because the runoff during September and October was as low as has been recorded and represents the most severe conditions. The flows during 1954 ranged from a high of 16,000 m.g.d. in January to a low of 175 m.g.d. in October. Except during the months of September and October and a few days in August, 1954, the flows of the Yadkin River at Styers Ferry were well in excess of 300 m.g.d.

It is evident from Exhibit 5 that except during a few weeks in the year, the withdrawal of 25, 50 or even 100 m.g.d. from the Yadkin River for water supply purposes would have only a small effect on the normal discharge of the river. Furthermore, it is anticipated that ½ of the water taken from the Yadkin River for water supply purposes would be returned to streams in the Yadkin River basin. Most of the return water would be discharged through Muddy Creek into the Yadkin River only a few miles below Styers Ferry. Thus, the effect of diversion from the river would be even less than indicated by the pumping rates.

The low flows in 1954 and 1956 were the result of unusually low rainfall, which normally would not occur except at intervals of several years. We recognize, however, that a large number of farm ponds have been and are being constructed on the headwaters of the Yadkin River. These ponds are small, but in the aggregate they represent storage of many millions of gallons of water. The effect of farm ponds is to reduce low flows downstream, since the normal runoff is held for use by the farmer. We cannot estimate how much farm pond construction will reduce the low flows of the Yadkin River, but some diminution in flow should be expected.

Effect of Diversions on Downstream Water Users

The effect of diversions from the Yadkin River for a regional water supply would depend upon the magnitude of the diversions and when they were made. Some downstream water users are geared to local stream flows, and any substantial diminution in flow would be noticeable. Other users have storage reservoirs that compensate for periodic reductions in flow. These users would not be affected to any important degree. For the most part, diversions of water to the seven cities during periods of relatively large runoff would have no measurable effect on downstream users.

The effects of diverting Yadkin River water for the seven cities are summarized briefly in the sections following. The water uses between Donnaha and Styers Ferry are insignificant, and these comments pertain equally to either intake site.

a. Municipal Water Supplies

There are 64 public water supplies in the Yadkin River basin in North Carolina. Of these 36 supplies have ground water sources yielding a total of 12 m.g.d.; 28 supplies take their water from surface water resources and have a total capacity of 75 m.g.d. Most of the surface water supplies are taken from small reservoirs on tributary streams and would not be affected by diversions of water from the main stem of the Yadkin River.

The six municipal water supplies in North Carolina on the Yadkin River below Styers Ferry are as follows:

Public Water Supplies from Yadkin River

	Population		Rated Capacity Filter Plant	
Albermarle..........	13,100		4.0	M.G.D.
Badin................	3,000		1.5	"
Mount Gilead........	1,500		0.25	"
Norwood............	2,150		0.50	"
Salisbury............	26,600		4.00	"
Winston-Salem.......	100,000	part	20.00*	"
			30.25	

*Salem Creek Reservoir furnishes 9.0 m.g.d. The deficiency in supply is met by pumping from the Yadkin River at Idols.

Cheraw, S. C., a community of approximately 5,000 persons, obtains its water supply from the river further downstream.

As indicated by the table above, the total potential municipal water consumption in cities served by the main stem of the Yadkin River is about 10% of the low flows of 200-300 m.g.d. If we eliminate the Winston-Salem Yadkin River supply as now developed, the ratio is less than 5%. Most of the water used in the cities returns to the Yadkin River as sewage or industrial waste, and the consumptive use of water is negligible. As far as we can see, the diversion of water supply for the seven cities would not affect appreciably the municipal water supplies downstream even if these downstream requirements should double and redouble in the next 50 years. This comment applies particularly to those several communities which take their water from large hydroelectric power reservoirs on the Yadkin River.

b. Irrigation

Supplemental irrigation of crops and grazing land is increasing throughout the southeastern states. The total water requirements for irrigation are not large, because one or two applications during a growing season are usually sufficient. A total annual water consumption for irrigation of 12 inches would be high in most instances. The average is probably ¼ to ½ as much. Most of the water for irrigation is obtained from small farm ponds on the headwaters of tributary streams. There is little or no pumping of irrigation water from the main stem of the Yadkin River or principal tributaries. Permits must be obtained from the Department of Conservation and Development for the construction of farm ponds for irrigation. In 1955, 5,540 acres of farm land were covered by such permits.

It is reasonable to expect that irrigation will grow, particularly along the tributary streams. Farmland along the banks of the Yadkin River enjoying riparian rights are limited in area, and the quantity of water required to irrigate it is not likely to be significant.

It is possible that farmers will join together to establish irrigation districts with intakes and pumping stations serving a number of farms. In this case the water used will be obtained by diversion, rather than as a riparian right. While the North Carolina law is not specific as to preferred water uses, there is little reason to believe that the irrigators would have priority over a municipal water supply for the seven cities.

c. Hydroelectric Power

There are a number of hydroelectric power plants on the Yadkin River below Styers Ferry. Pertinent data relating to each are summarized below:

Project	Stream	D.A. s.m.	Total Head	Power Storage a.f.	Power Draw-Down Feet	Installed Capac. k.w.	Dependable Capac. k.w.
Blewett Falls...	Pee Dee	6,860	51	10,000	8	24,600	24,600
Norwood (Tillery).......	Pee Dee	4,600	75	30,000	6	62,000	62,000
Falls...........	Yadkin	4,140	53	......	.	20,300	20,300
Narrows (Badin).......	"	4,120	179	130,000	28	81,200	81,200
High Rock.....	"	3,930	62	173,000	16	33,000	26,400
Idols...........	"	1,905	10	....	.	1,411	1,411
Reference:....			430	343,000		222,511	215,911

Ho. Doc. 652, 78th Congress, 2nd Session, 1944.

The Blewett Falls and Norwood plants are owned by the Carolina Power and Light Co.; Falls, Narrows and High Rock are owned by the Carolina Aluminum Co.; and the Idols plant by the Duke Power Co. The hydroelectric plants are interconnected with other generating plants and the discharges from the reservoirs are regulated for most economical power production. The Duke Power Company's Buck plant near Salisbury, with a capacity of 440,000 k.w., is the largest steam plant in the vicinity.

The Carolina Aluminium Co. has applied to the Federal Power Commission for a license to develop an additional 57 feet by the construction of a new dam at the Tuckertown site between High Rock and Narrows.

The location of the hydroelectric plants in relation to the tributaries of the Yadkin River has an important bearing on the effects of pumpage at Styers Ferry or Donnaha because much of the water pumped from either site would return to the Yadkin River above the largest power plants. All of the plants except Idols are located below Muddy Creek and Abbotts Creek, which drain much of the area to be served, and presently carry off the sewage and industrial wastes from Winston-Salem, Thomasville and Lexington, and from parts of Kernersville and High Point. The total water consumption in these cities is estimated at 60 per cent of the total pumpage from the Yadkin River. Allowing 10 per cent loss, the return

flow to the Yadkin River through Muddy Creek and Abbotts Creek would total 54 per cent of the pumpage. The remainder would be discharged from Greensboro, Burlington and parts of Kernersville and High Point into the Cape Fear River basin. Thus, of the six hydroelectric plants, only the low head plant at Idols would suffer from 100 per cent loss of water.

The maximum possible loss in hydroelectric power can be estimated by assuming that all water diverted, less water returned above the lower plants, could be used effectively in all six downstream plants. In this case the water-head loss would be as follows:

	Idols—10′		Other Plants 420′		Total Daily Power Loss		
Av. Pump. m.g.d.	Water Loss m.g.d.	Loss x Head	Water Loss m.g.d.	Loss x Head	Loss x Head (E)	k.w.h.	@0.7¢
20	20	200	9.2	3,860	4,060	10,800	$ 76
40	40	400	18.4	7,740	8,140	21,700	152
60	60	600	27.6	11,600	12,200	32,500	228
80	80	800	36.8	15,500	16,300	43,400	304
100	100	1000	46.0	19,300	20,300	54,000	378

1 m.g.d. falling 100′ @ 85% efficiency yields 11.1 k.w.
Daily Power Loss = .111 x 24 x E = 2.66 E k.w.h.
Value of Power at bus bar = 7 mils/k.w.h.
Value of lost hydro power = $\frac{76}{20}$ = \$3.80 per m.g. pumped.

Maximum Annual Lost Power

Pumpage M.G.D.	Dollars
20	$27,800
40	55,500
60	83,300
80	111,000
100	138,000

Actually, the Yadkin River reservoirs are not large enough and the power plants are not equipped to utilize the full flow of the river. During periods of high river discharge the diversion of water to the seven cities would have little or no effect on power production. The useful, or power, storage in the six reservoirs totals 343,000 acre-feet, or 112,000 million gallons. If these reservoirs were all regulated to best advantage, the storage would assure a steady flow not exceeding 40 per cent of the mean discharge, and much of the time water is necessarily wasted. The same conclusion is reached by consideration of the maximum quantities of water that can be passed through the water wheels at the several plants. While the capacity varies at each plant, it appears that the limit is 3,200 to 4,000 m.g.d., except at Norwood, which is about twice as large, and at Idols, which is much smaller. The daily discharge of the Yadkin River at the High Rock gage exceeds 3,200 m.g.d. at least 75 to 100 days in each year. At these times, there is excess water spilling over the dams, and the diversion of water to the seven

cities would have no effect. For this reason the actual power loss would be considerably less than the amounts calculated in the previous table.

The previous computations are based upon average pumpages and power generation. If water were diverted at high rates during dry periods, when river flows were low, the water loss would be felt more keenly at the downstream power plants. However, the low-flow periods are likely to occur during summer and fall months, when power demands are not at a maximum, and there is some doubt that the loss of water then actually would be as serious as at other times in the year. If the power plants are used as "peaking plants," the value of power lost may be somewhat higher than we have assumed. These factors would have to be studied in detail later if the Carolina Aluminum Co., the Duke Power Co., and the Carolina Power & Light Co. should enter serious objections to diversion of water to the seven cities. For the present the important point is that if the diversion of water does harm the downstream power plants, the loss in power would not exceed $3.00 more or less per million gallons of water pumped. This is equivalent to 0.22¢ per hundred cubic feet, which is relatively small, when compared to retail water rates of 10 to 30¢ per hundred cubic feet.

d. Industrial Water Supply

There are only two industrial water supplies of any size taken from the main stem of the Yadkin River below Styers Ferry. The North Carolina Finishing Co. at Spencer uses 1 to 2 m.g.d. The Buck Steam Power Plant of the Duke Power Co. requires large quantities of condenser cooling water. The cooling water demand is equivalent to the total flow of the Yadkin River past the power plant during drought periods. Duke Power Co. officials have indicated that when and if the Buck plant is enlarged, the low flows will be insufficient for condenser purposes, and cooling towers will have to be built. The diversion of water to the seven cities at periods of low flow would aggravate this situation. However, the cost of building and operating cooling towers for condenser water is so small in relation to the value of water for municipal purposes that no serious difficulty should be expected.

e. Navigation

Commercial navigation is of no importance on the Yadkin River in North Carolina. Further downstream in South Carolina, where there is some shipping, particularly along the coast, the total flows of the river are much greater, and the proposed diversions would have no appreciable effect.

f. Recreation

The Yadkin River and the several lakes behind power dams are used extensively for boating, fishing and bathing. None of these uses should be affected adversely by diversion of the quantities of water contemplated.

Legal Considerations

The pumpage of water from Donnaha or Styers Ferry to the seven cities would constitute a diversion of water from the Yadkin River basin. Diversions of water for municipal purposes are common in the eastern states, but there have been

few such cases in North Carolina. Minor diversions of this type are presently made at Blowing Rock, where the municipal water supply is taken from the New River basin and part of the sewage is discharged into the Yadkin River basin . . . at High Point, where the water supply is taken from the Deep River, and some of the sewage is discharged to the Yadkin River basin . . . at Mooresville and Davidson, where water is taken from the Catawba River, and discharged to the Yadkin River basin . . . and at Asheboro, where the water supply is taken from the Yadkin River, and part of the wastes go to the Cape Fear River basin. In these instances the quantities of water involved are small, and apparently no serious objection has been raised.

The seven cities have no riparian rights in the Yadkin River. They could not establish such rights simply by building an intake dam and pumping station. North Carolina water law is based upon the riparian rights doctrine, under which all riparian landowners are entitled to equal use of the water passing their properties. The state courts in applying this doctrine have introduced the element of "reasonable use." Damage claims on account of upstream diversions have been denied by the courts where the lower riparian owner has been unable to prove significant reduction in flow and actual damages.

There is interest in North Carolina and other eastern states directed toward the establishment of the appropriation doctrine in place of the riparian doctrine. The appropriation doctrine is applied exclusively in the arid and semi-arid states of the west, and has distinct advantages where the water supply is limited. Under the appropriation doctrine, a water user establishes a right to beneficial use of water by filing an application with the proper state authority, building the necessary works and using the water. Under this doctrine the first in time is the first in right, and as long as the beneficial use is not interrupted, the right to diversion is protected. Downstream riparian owners have no special claim to water simply because their land happens to adjoin the stream. Beneficial uses under the appropriation doctrine include all of the ordinary uses of water, including municipal and industrial water supply, hydroelectric power generation, irrigation, etc.

In areas of limited water supply the benefits of the appropriation doctrine are well recognized. As the available water supplies of the east are used up, it seems likely that this doctrine or some modification of it will spread to the states now using the riparian rights doctrine. The transition will not be quick or easy, because of the thousands of vested rights under the old doctrine. The courts in riparian rights states have consistently held that failure of a riparian owner to use water from the stream does not invalidate his right to do so. Therefore, strictly interpreted, every riparian landowner has water rights which cannot be disposed of without proper legal action. Furthermore, the right to the water use passes with the land on to his heirs or the next owner.

This brief statement of water law and policy obviously is incomplete and oversimplified. It is intended merely to indicate the general nature of the problem.

Regulation of water use in North Carolina is certain to be an important issue in years to come. The debate over different procedures and demands for general and special legislation may delay construction of a regional water supply such as proposed on the Yadkin River for the seven cities. However, if the people want such a supply, it undoubtedly can be accomplished. As competition for water increases in North Carolina, the legislature and courts are sure to see that the most

pressing demands are met. The seven cities project should fare well in such competition for a number of reasons:

(1) The prosperity and welfare of a segment of North Carolina will be dependent upon the development of an adequate water supply.

(2) Equally important, the health and welfare of the seven cities area will be jeopardized by inadequate sewage and waste disposal if the local streams are developed exclusively for water supply purposes.

(3) Wherever priority of use has been established by legislation or has been an issue in the courts, municipal water supply has always been placed near the top of the list.

(4) The quantity of water to be diverted from the Yadkin River is insignficant in relation to the total flow of the stream. Damage to downstream users would not be excessive. In any event, the extent of damages can be established under the normal processes of law and paid for. The cost of such damages would be small in relation to the total cost of the project and would not affect the price of water appreciably.

(5) If the water resources of the Yadkin River are developed further by the construction of storage reservoirs, as discussed in the next section of the report, the effects of diversion would be eliminated for all practical purposes.

Value of Upstream Storage

As noted in the previous section, the diversion of Yadkin River water to the seven cities would be noticeable only in periods of low flow. If these low flows were increased by releases from upstream reservoirs, the effect of such diversion would be eliminated.

For a number of years the Corps of Engineers has studied the feasibility of flood control and hydroelectric power reservoirs on the Yadkin River. Existing and proposed reservoirs are shown in Exhibits 6 and 7. Of the proposed reservoirs, the Wilkesboro reservoir is most likely to be built in the near future. This reservoir would have a usable storage of 328,000 acre-feet (100,000 m.g.) and would be built essentially for flood control purposes. The District Engineer has indicated that a "conservation pool" would be provided in the reservoir to assure releases of at least 65 m.g.d. during periods of low stream flow. If a second reservoir is built on Reddies River nearby, the low flow releases would be increased to 100 m.g.d. These releases would exceed the maximum diversions for a seven cities water supply for years to come, and should eliminate entirely the question of damages to downstream riparian owners.

The construction of the Wilkesboro reservoir as proposed by the Corps of Engineers would be of substantial help to the seven cities.

A smaller storage reservoir for water supply purposes alone could be built. However, in this case, the unit cost would be much greater because of necessary allowances for siltation in a main stem reservoir, or more costly construction if the reservoir were built on one of the tributary streams.

8. DESCRIPTION AND COST ESTIMATES—YADKIN RIVER PROJECTS

General Considerations

Regardless of which intake site is selected, or whether a raw water or filtered water project is built, the following works must be provided on the Yadkin River:

(1) An intake pool 10 feet deep to be formed by a low dam across the river.

(2) A spillway to discharge the maximum flood, estimated at 240,000 c.f.s.

(3) A raw-water pumping station, including intake screen, pump suction well, facilities for flushing silt from the well, and electric-motor-driven pumps and power supply.

The intake dam and pumping station structure would be built to the ultimate capacity. The initial pump installation and electric equipment would be limited to first-stage requirements, but space would be provided for the addition of larger units. The cost estimates are based upon the initial installation of two 10 m.g.d. and one 20 m.g.d. pump. The pumps would be vertical pumps, submerged in the pump well with electric motors mounted on the pumping station floor above, where there would be no danger of flooding. Electric power for the pumping station would have to be brought to the site from the high-tension lines of the Duke Power Co. about 5 miles away. The sale of power would be profitable, and the Duke Power Co. undoubtedly would assume the cost of the service line upon assurances of a reasonable consumption over a period of years.

DONNAHA SITE—INTAKE WORKS

The Donnaha site has been mapped by the Corps of Engineers and the subsurface conditions determined in a preliminary way by test borings. The cross-section of the Yadkin River valley at Donnaha is shown in Exhibit 10. The rock line is approximate only. Some of the District Engineer's records at Charleston, S. C., were destroyed by fire, and it has not been possible to locate the borings exactly.

On the east side of the river the rock is close to the ground surface and would provide support for a concrete spillway structure and pumping station. On the west side of the river the rock falls away rapidly and could be reached only by structures of considerable depth. Therefore it is proposed that the masonry structures be confined to that part of the river within 600 feet of the east bank and that an earth-fill dam be used on the western side. The underlying rock is of shale, badly fractured and weathered near the surface. For a high storage dam the rock unquestionably would have to be thoroughly grouted with cement to prevent excessive leakage. For a low intake dam the water pressure on the rock would be much less and grouting should not be a serious problem.

Two types of intake dam have been studied. In the first the dam would consist of a simple concrete ogee spillway section with crest at elevation 744. In the second the sill would be held at elevation 734 and the extra 10-foot depth would be

provided by means of roller or tainter gates. The gates would be opened during flood flows, and the earth portion of the dam could be lower than with the fixed spillway. The general arrangement of the structures is shown in Exhibit 10. The intake screen, pumping well and pumping station would be substantially the same with either type. The project cost with the two types of dam are estimated as follows; exclusive of allowances for engineering or contingencies:

DONNAHA INTAKE DAM AND PUMPING STATION

	Unit Price	Overflow Weir Quantities	Overflow Weir Cost	Gated Design Quantities	Gated Design Cost
Land......	$250.00	400 A.	$100,000	400 A.	$100,000
Flowage Rights......	25.00	1200 A.	30,000	1200 A.	30,000
Sub-Total......			$130,000		$130,000
Dam					
Clearing & Grubbing..	200.00	10 A.	2,000	10 A.	2,000
Earth Fill...........	1.00	17000 CY	17,000	25200 CY	25,000
Earth Excavation....	1.00	49500 CY	49,500	35780 CY	35,780
Rock Excavation.....	5.00	9650 CY	48,250	7340 CY	36,700
Concrete-lt. Secs......	60.00	....	..	3325 CY	199,500
Concrete-Massive....	40.00	24370 CY	974,800	14310 CY	572,400
Gates...............	L.S.	....	....	....	234,000
Stream Diversion.....	L.S.	....	250,000	....	250,000
Sub-Total.......			$1,341,550		$1,355,580
Pumping Station					
Earth Excavation....	1.00	20400 CY	20,400	10200 CY	10,200
Rock Excavation.....	5.00	236 CY	1,180	140 CY	700
Concrete-lt. Secs......	60.00	2840 CY	170,400	3050 CY	183,000
Pumps and Motors...	L.S.	....	160,000	....	160,000
Pumps Install. and Switchgear......	L.S.	....	64,000	....	64,000
Sub-Total.......			$415,980		$417,900
Grand Total.....			$1,887,530		$1,903,480
Use.............			$1,900,000		$1,900,000

The estimated costs would be practically the same, whichever type of dam were used. Since the overflow weir is the more reliable and requires no operating or maintenance expense, it probably would be the preferable type. Additional borings at the site and detailed design studies should be made before a final decision is reached. For purposes of project estimates the $1,900,000 figure has been used.

STYERS FERRY SITE—INTAKE WORKS

The Styers Ferry site has been explored by the Corps of Engineers and by the City of High Point, which proposed to build a municipal hydroelectric power plant there several years ago. As a result of these studies, the site is well mapped and adequate borings are available. A cross-section of the site is shown in Exhibit 11.

The geology at Styers Ferry is much the same as at Donnaha, except that the underlying rock does not fall off so rapidly towards the west.

An ogee spillway section and gated structure have been studied for the Styers Ferry site. The overflow spillway would be 600 feet long with crest at elevation 692. The gated spillway would be 500 feet long with a sill at elevation 680, and supporting gates 12 feet high.

At the Styers site the project with fixed overflow section is estimated to cost $1,800,000. The project with gated structure would cost $1,700,000. The difference is relatively small in terms of the over-all project cost, and a final decision as to the type of dam should be delayed until after more detailed design studies have been completed. The higher figure, $1,800,000, is used in subsequent estimates to be on the safe side. The cost breakdown for the two types of construction is summarized as follows:

STYERS FERRY INTAKE DAM AND PUMPING STATION

	Unit Price	Overflow Weir Quantities	Overflow Weir Cost	Gated Design Quantities	Gated Design Cost
Land	$250.00	200 A.	$ 50,000	200 A.	$ 50,000
Flowage Rights	25.00	2500 A.	62,500	2500 A.	62,500
Sub-Total			$112,500		$112,500
Dam					
Clearing & Grubbing	200.00	11 A.	2,200	11 A.	2,200
Earth Fill	1.00	26650 CY	26,650	28290 CY	28,290
Earth Excavation	1.00	53190 CY	53,190	34480 CY	34,480
Rock Excavation	5.00	12170 CY	60,850	7590 CY	37,950
Concrete-lt. Secs.	60.00	....	......	2810 CY	163,600
Concrete-Massive	40.00	20550 CY	822,000	9690 CY	387,600
Gates	L.S.	....	....	....	234,000
Stream Diversion	L.S.	....	250,000	....	250,000
Sub-Total			$1,214,890		$1,138,120
Pumping Station					
Earth Excavation	1.00	18320 CY	18,320	9380 CY	9,380
Rock Excavation	5.00	270 CY	1,350	240 CY	1,200
Concrete-lt. Secs.	60.00	3460 CY	207,600	3120 CY	187,200
Pumps and Motors	L.S.	....	160,000	....	160,000
Pumps Install. and Switchgear	L.S.	....	64,000	....	64,000
Sub-Total			$ 451,270		$ 421,780
Grand Total			$1,778,660		$1,672,400
Use			$1,800,000		$1,700,000

Comparison of Intake Sites

From the standpoint of construction costs the Donnaha and Styers Ferry sites are practically on a par. At the Donnaha site the water level would be at elevation 744, or 52 feet higher than at the Styers Ferry site. The pumping head, therefore, would be less with the Donnaha intake site. It should be noted, however, that if the proposed hydroelectric power dam is built at Styers Ferry, it will back the water up to elevation 750 and flood out by 6 feet the intake dam at Donnaha. It is assumed that if the intake were built at Styers Ferry, the pumping station would be moved upstream above the new dam in order to take advantage of the higher water level. Thus, the pumping head at Donnaha and Styers Ferry ultimately might be the same.

The Corps of Engineers has studied also a power dam at Donnaha, which if built would raise the water level there by 148 feet to elevation 877. However, the Corps of Engineers' studies prove little economic justification for the Donnaha dam, and, if it is ever built, it is likely to be the last undertaken on the Yadkin River.

DONNAHA SITE—RAW WATER PROJECT

The location of the Donnaha intake site and raw water transmission main are shown in Exhibit 8. The pipeline would follow a direct route from the intake across the northern part of Winston-Salem, near the airport, and continue to Kernersville. An approximate plan and profile along this line is shown in Exhibit 12 upon which is also shown the hydraulic gradients for various flows as indicated. The ground rises steeply from the Yadkin River to elevation 910 plus, continues for a distance of 10 miles in general between elevation 800 and 900, and rises to high points at elevation 1,000 north of Winston-Salem and 1020 at Kernersville.

The pipeline would be 54 inches in diameter to the first takeoff northeast of Winston-Salem, some 16 miles from the river. Raw water for Winston-Salem would be discharged here into the headwaters of Lowery Creek to feed the Winston-Salem reservoir. The line would be reduced to 48 inches at the Winston-Salem take-off, and the remaining flow discharged through the 48-inch pipeline 5½ miles long to a distribution reservoir to be provided at Kernersville. The Kernersville reservoir would have a flow line at elevation 1030. Water would be released from the Kernersville reservior through pipelines of various lengths and sizes into the headwaters of the streams feeding the supplies of the several communities, as indicated on Exhibit 14. Thus, water would be discharged into the Haw River for Burlington, into Reedy Fork Creek for Greensboro, into the Deep River for High Point and into Abbotts Creek for Lexington and Thomasville. Raw water for Kernersville would take off nearest the filter plant and discharge directly into the mixing chamber at the plant.

Hydraulic profiles for assumed pumping rates of 10, 30 and 50 m.g.d. are shown in Exhibit 12. In preparing these profiles, the water consumption was distributed as follows:

Winston-Salem	35%	Lexington	5%
Greensboro	30%	Thomasville	4%
High Point	15%	Kernersville	1%
Burlington	10%		100%

These percentages are approximately in proportion to the estimated future water consumption in the seven cities. They include not only the water consumption within the city, but also that to be taken in the suburban areas expected to build up adjacent. All water pumped, except the 35% delivered to Winston-Salem and that taken by Kernersville would be delivered to the Kernersville reservoir for distribution to the remaining cities in the proportion indicated. The actual water consumption might differ substantially from the assumed percentages, particularly in the smaller communities, without changing materially the hydraulic conditions.

In the initial stages of the project, when the pumping was less than 30 m.g.d., it would be more convenient and very nearly as economical to pump all the way from the Yadkin River to the Kernersville reservoir, and our profiles are shown on this basis. A booster pumping station could be built at the Winston-Salem takeoff at a later date when more capacity was needed in order to avoid pumping the water used by Winston-Salem the extra height necessary to reach the Kernersville reservoir. The total pumping head would depend upon the pumping rate. Typical values are as follows for pumping through to the Kernersville reservoir:

Raw-Water Project with Donnaha Intake

Pumping Rate	Total Head
10 m.g.d.	294
30 m.g.d.	336
50 m.g.d.	414

If a receiving basin and booster pumping station were provided now at the Winston-Salem takeoff, pumping heads from the river could be reduced by 20 feet for the low rate of 10 m.g.d. and still deliver over the hump north of Winston-Salem. Pumping heads would then be as follows:

Raw-Water Project with Donnaha Intake

Pumping Rate	Head at Yadkin	Pumping Rate	Head at Booster Pump
10 m.g.d.	274	6.5 m.g.d.	20
30 m.g.d.	300	19.5 m.g.d.	36
50 m.g.d.	350	32.5 m.g.d.	64

Attention should be called to the fact that if raw water is delivered to the several cities, it will be necessary, except for Winston-Salem and Kernersville, to repump this raw water from the existing city supplies to their treatment works. Burlington would also have to repump the quantity delivered to them from their Haw River emergency intake to their existing storage.

The cost of a raw water project from the Yadkin River at Donnaha, including the intake and pumping station costs, is estimated as follows:

DONNAHA SITE RAW WATER PROJECT ESTIMATE OF COST

Supply Works and Transmission Mains				
Diversion Dam Intake Works and Pumping Station				$ 1,900,000
Real Estate and Rights-Of Way Raw Water Line				140,000
Rock Excavation Pipe Line	10,000 c. y.	@	10.00	100,000
Highway and Railroad Crossings	L.S.			144,000
54″ Class 200 Lock Joint Pipe	84,000 ft.	@	47.50	3,990,000
48″ Class 150 Lock Joint Pipe	29,200 ft.	@	34.50	1,007,400
Misc. Valves, Gates, Meters and Structures				490,450
25 M.G. Concrete Uncovered Reservoir at Kernersville				508,000
Sub-Total System Cost				$ 8,279,850
Engineering and Contingencies 15%				1,241,980
Total Estimated System Cost				$ 9,521,830
Use				$ 9,600,000

Distribution Mains from Kernersville Reservoir		
To Haw River for Burlington	15,000′-16″	155,500
To Reedy Fork for Greensboro	1,000′-30″	25,400
To Deep River for High Point	6,000′-24″	118,100
To Kernersville Filter Plant	3,000′-16″	38,700
To Abbotts Creek for Lexington and Thomasville	8,000′-16″	104,200
Winston-Salem Takeoff from Main Line	300′-30″	12,800
Sub-Total Diversion Lines Cost		$ 454,700
Engineering and Contingencies 15%		68,210
Total Estimated Cost Diversion Lines		$ 522,910
Use		530,000
Use Total Estimated Cost of		$10,130,000

The raw water supply project including intake works, pumping station, transmission main and reservoir at Kernersville would cost $9,600,000. The distribution lines from the Kernersville reservoir to the streams would cost $530,000. It is assumed that all seven cities would share the cost of the supply works to the Kernersville reservoir but that each city would pay for its own distribution main.

The cost of raw water distribution mains for each city, including engineering and contingencies, would be as follows:

Burlington	$180,000
Greensboro	30,000
High Point	138,000
Kernersville	45,000
Lexington & Thomasville	122,000
Winston-Salem	15,000
	$530,000

The raw-water system described above would have a capacity of 50 m.g.d. throughout, except that additional pumps would have to be installed in the pumping station. Provision would be made in the original construction for adding pumps later, and the cost would be limited to the pumps, motors, switchgear and installation. An allowance of $200,000 is made for this in later estimates.

DONNAHA SITE—FILTERED WATER PROJECT

In the filtered water project using the Donnaha Site, the pipeline would follow the same route shown for the raw water project. The river pumping station would lift the water to a filter plant located about three miles from the river northwest of Winston-Salem. A suitable site exists at elevation 940 for the filter plant and filtered water pumping station. Its location is indicated on Exibits 9 and 12. The pipeline would continue past Winston-Salem to Kernersville. However, in this case the water for Winston-Salem would be taken off north of the city and pumped directly into the Winston-Salem high level distribution system. Shifting the Winston-Salem takeoff to the west would reduce the length of 54-inch pipe and increase the length of 48-inch pipe by about three miles.

In the filtered water project, all water would be pumped to the filter plant and then repumped to the same elevation as previously indicated for raw water. This is high enough to serve Winston-Salem through low head pumps and deliver the balance of the water into a distribution reservoir at Kernersville without repumping. System pumping heads to Kernersville for the various rates indicated are as follows. Twenty feet head loss is allowed through the filter plant.

	Total Pumpage to All Cities		
	10 M.G.D.	30 M.G.D.	50 M.G.D.
Yadkin River to Filter Plant—ft.....	197	203	214
Filter Plant to Kernersville Reservoir—ft....................	117	153	220
Total feet.....................	314	356	434

From the reservoir at Kernersville, water could be delivered to the corporate limits of Greensboro, High Point, Thomasville and Lexington without further pumping. However, under certain conditions, pumping would be required at each of these four cities to elevate the water into the existing distribution system tanks. Static pumping heads would vary inversely with the system delivery rate through the transmission mains. Burlington's needs could be delivered directly to the distribution system without further pumping. Water for Kernersville would be delivered directly to the existing clear water reservoir at the filter plant without pumping. Reference is made to Exhibits 15, 16, 17 and 18 for location plans and profiles of the transmission mains from Kernersville.

It is assumed that each of the seven cities would take treated water from the transmission mains at the most convenient point and pump their needs into their own distribution system through pumping equipment and lines which they would own and operate. Water to Kernersville could be delivered directly to the existing clear water reservoir with little loss of head and repumped with existing pumps. Water could be delivered to Burgington's distribution system directly without repumping up to a rate of over 4 M.G.D.

The remaining 5 cities, under certain conditions, would need to pump against varying heads depending upon the delivery rates through the system transmission mains. Static heads between the elevations of the several distribution systems, and the hydraulic gradient in the adjacent transmission main at varying rates of flow in the mains would be as tabulated below. Friction heads between transmission mains and distribution systems are not included.

System Draft		10 M.G.D.		30 M.G.D.		50 M.G.D.	
	%	m.g.d.	Ft.	m.g.d.	Ft.	m.g.d.	Ft.
Greensboro	30	3.0	−21	9.0	.	15.0	36
High Point	15	1.5	71	4.5	103	7.5	159
Lexington	5	.5	−103	1.5	−36	2.5	81
Thomasville	4	.4	−24	1.2	27	2.0	115
Winston-Salem	35	3.5	62	10.5	47	17.5	19

Negative figures indicate gravity flow to distribution systems without pumping.

It should be noted that no additional pumping head would be required at Greensboro and Lexington for system rates of 10 and 30 m.g.d., and none at Thomasville for the lower rate of 10 m.g.d. It should be further noted that pumping heads at Winston-Salem decrease with the increase in system delivery, because the level control is at Kernersville some 8½ miles beyond the point of takeoff.

The cost of a filtered water project from the Yadkin River at Donnaha, including all works through the Kernersville reservoir and filtered water distribution mains, but excluding connection lines and pumps between the distribution mains and the individual cities, is estimated as follows:

DONNAHA SITE—FILTERED WATER PROJECT
ESTIMATE OF COST

Supply Works, Filter Plant and Transmission Main		
Diversion Dam-Intake Works and Pumping Station		$ 1,900,000
54" Class 200 Lock Joint line to Filter Plant including right-of-way and all accessories	15,000'	777,000
Filter Plant complete with Controls and Pump Station 30 M.G.D. Capacity @ $175,000 per M.G.		5,250,000
Real Estate for Plant	50 Acres @ 350.00	17,500
Pipeline to Kernersville Reservoir		
Real Estate and Rights-Of-Way—Pipeline		125,000
Rock Excavation Treated Water Line	8,500 c. y.	85,000
Highway and Railroad Crossings	L.S.	119,000
54" Class 200 Lock Joint Pipe	54,000 ft. @ 47.50	2,565,000
48" Class 150 Lock Joint Pipe	44,200 ft. @ 34.50	1,524,900
Misc. Valves, Gates, Meters and Structures		435,850
25 M. G. Concrete Covered Reservoir at Kernersville		810,000
Sub-Total System Cost		$13,609,250
Engineering and Contingencies 15%		2,041,390
Total Estimated System Cost		$15,650,640
Use		$16,000,000
Distribution Mains		
Kernersville Reservoir to Greensboro	82,600'-12"	2,613,500
Greensboro to Burlington	100,900'-20"	1,509,975
Kernersville Reservoir to High Point	63,400'-30"	1,346,200
High Point to Thomasville	31,100'-20"	478,125
Thomasville to Lexington	27,400'-16"	318,800
Sub-Total Distribution Mains		$ 6,266,600
Engineering and Contingencies 15%		939,990
Total Estimated Cost Distribution Mains		$ 7,206,590
Use		$ 7,200,000
Use Total Estimated Cost of		$23,200,000

The preceding estimate of cost for the filtered water project at the Donnaha site is based on a capacity of 50 m.g.d. except for the filter plant and pumping stations which would have an initial capacity of 30 m.g.d. The only increase needed to bring the over-all capacity up to 50 m.g.d. would be the addition of 20 m.g.d. capacity to the filter plant and pumping stations. Real estate estimated for the filter plant site is sufficient for the ultimate estimated capacity in the year 2000. The addition of 20 m.g.d. capacity is estimated to cost $3,500,000.

It is assumed that the $16,000,000 cost of the supply works, filter plant, transmission main and reservoir at Kernersville would be shared by all of the seven cities. The distribution mains from the reservoir would be paid for by the cities using them. Kernersville and Winston-Salem would draw their needs directly from the feeder main to the reservoir and would not need to construct separate distribution mains from the reservoir to the cities. During periods when pumps were not operating, the main feeder would serve as a distribution main from the reservoir back to Kernersville and Winston-Salem. The cost of distribution mains, for the five remaining cities, including engineering and contingencies, would be as follows:

Filtered Water Project—Both Sites			Use
Kernersville to Greensboro	82,600′-42″	$3,005,525	$3,000,000
Greensboro to Burlington	100,900′-20″	1,736,470	1,740,000
Kernersville to High Point	63,400′-30″	1,548,130	1,550,000
High Point to Thomasville	31,100′-20″	549,845	545,000
Thomasville to Lexington	27,400′-16″	366,620	365,000
Total		$7,206,590	
Use total Estimated Cost of			$7,200,000

Some of these distribution mains would serve more than one city. The allocation of these costs, and over-all water costs, among the several cities, is taken up in detail in Section 9 of the report. On the basis of that analysis the cost of building distribution mains would be charged to each city, as follows:

Amount of above chargeable to	Burlington	$2,190,000
" " " " "	Greensboro	2,550,000
" " " " "	High Point	1,085,000
" " " " "	Lexington	865,000
" " " " "	Thomasville	510,000
	Total	$7,200,000

STYERS FERRY SITE—RAW WATER PROJECT

The location of the Styers Ferry intake and raw water transmission main to Kernersville is shown on Exhibit 8. The pipeline would pass south of Winston-Salem and then almost due east to a raw water storage reservoir at Kernersville, where the water would be distributed as described in the Donnaha Project. An approximate plan and profile along the proposed line similar to that for the Donnaha project is shown in Exhibit 13. The ground is cut frequently by creek valleys 100 to 150 feet deep, but otherwise rises steadily from the Yadkin River to Kernersville.

The first 17 miles of pipeline to the Winston-Salem takeoff would be 54-inch

diameter pipe, terminating in a small storage reservoir. The remaining 6.7 miles to the Kernersville reservoir would be 48-inch pipe. Water would be delivered to Winston-Salem from the storage reservoir through a 30-inch pipe 3000 feet long into the headwaters of a small creek, flowing into the Salem Creek reservoir as indicated on Exhibit 13. The remaining water would be repumped through the 48-inch main to the Kernersville reservoir. For the Styers Ferry Raw Water Project, the pumping heads would be as follows:

Pumpage M.G.D.	Lift At Yadkin River In Feet	Booster Pumping Station Pumpage M.G.D.	Lift In Feet
10	251	6.5	93
30	288	19.5	104
50	353	32.5	125

In this case the savings in pumping costs by repumping after the Winston-Salem takeoff would be considerable and double pumping would be warranted even at low flows. Distribution from the Kernersville Reservior would be the same as described for the Donnaha Reservoir. Reference is made to Exhibit 14.

The cost of a raw water project from the Yadkin River at Styers Ferry, including the intake and pumping station costs, is estimated as follows:

STYERS FERRY SITE—RAW WATER PROJECT
ESTIMATE OF COST

Supply Works and Transmission Mains

Diversion Dam—Intake Works and Pumping Station				$ 1,800,000
Real Estate and Rights-Of-Way				155,000
Rock Excavation	11,000 c. y.	@	10.00	110,000
Highway and Railroad Crossings				141,000
54″ Class 200 Pipe	88,500 ft.	@	47.50	1,203,750
48″ Class 150 Pipe	35,200 ft.	@	34.50	1,214,400
Misc. Valves, Gates, Meters and Structures				518,850
3 M.G. Reservoir and Pump House at Winston-Salem Takeoff				160,000
Pumps, Motors and Controls—In place				118,000
25 M.G. Reservoir at Kernersville				508,000
Sub-Total System Cost				$ 8,932,000
Engineering and Contingencies 15%				1,389,800
Total Estimated System Cost				$10,321,800
Use				$10,400,000

Distribution Mains

To Haw River for Burlington	15,000′-16″	$ 155,500
To Reedy Fork for Greensboro	1,000′-30″	25,400
To Deep River for High Point	6,000′-24″	118,100
To Kernersville Filter Plant	4,000′-16″	49,300
To Abbotts Creek for Lexington and Thomasville	8,000′-16″	104,200
Winston-Salem Takeoff from Main Line	3,000′-30″	66,400
Sub-Total Diversion Line Cost		$ 518,900
Engineering and Contingencies 15%		77,840
Total Estimated Cost Diversion Lines		$ 596,740
Use		$ 600,000
Use Total Estimated Cost of		$11,000,000

STYERS FERRY SITE—FILTERED WATER PROJECT

In the Styers Ferry filtered water project, the pipeline would follow the same route as selected for the raw water project. The filter plant and filtered water pumping station would be located along the line, about two miles from the river, as shown in Exhibits 9 and 13. A suitable site at approximately elevation 830, and within easy reach of paved highways, is available at this location. Water would be pumped to the filter and repumped as described for the Donnaha Project.

The first large takeoff to serve Winston-Salem would be just east of N. C. Highway 150 where a storage reservoir would be provided and water for Winston-Salem pumped by the City to its low level distribution system. The transmission mains would be 54-inch from the filter plant to this reservoir and 48-inch for the remaining 12.2 miles to the Kernersville reservoir. Water would be repumped to the Kernersville reservoir for distribution to the various cities as previously described. Distribution conditions from Kernersville would be the same as for the Donnaha Filtered Water project.

System pumping heads to Kernersville for the various rates indicated are as follows: Twenty feet loss is allowed through the filter plant.

	Total Pumpage to All Cities		
	10 M.G.D.	30 M.G.D.	50 M.G.D.
Yadkin River to Filter Plant—feet	139	143	152
Filter Plant to Winston-Salem takeoff—feet	93	112	147
Total	232	255	299

Pumping heads from the Winston-Salem takeoff to the Kernersville reservoir do not apply to water taken by Winston-Salem. Heads from this takeoff would be as follows:

	Total Pumpage to Cities Except Winston-Salem		
	6.5 M.G.D.	19.5 M.G.D.	32.5 M.G.D.
Winston-Salem takeoff to Kernersville	133 ft.	154 ft.	192 ft.

Static heads to the low level distribution system of Winston-Salem would be 161 feet for all system delivery rates since the level is controlled at the takeoff point and does not vary with delivery rates. Static heads for the remaining cities would be identical to those required for the Donnaha project. Reference is made to Exhibits 15, 16 17, and 18.

The cost of a filtered water project from the Yadkin River at Styers Ferry, including distribution mains from Kernersville, but excluding connecting lines and pumps between system transmission mains and the individual cities, is as follows:

STYERS FERRY SITE FILTERED WATER PROJECT
ESTIMATE OF COST

Supply Works, Filter Plant and Transmission Mains		
Diversion Dam—Intake Works and Pump Station		$ 1,800,000
54″ Class 200 Pipeline to Filter Plant including Rights-of Way and all accessories 11,500′		615,450
Filter Plant complete with Controls and Pump Station 30 M.G.D. capacity @ $175,000 per M.G.		5,250,000
Real Estate for Filter Plant 50 Acres @ $350.00		17,500
Pipeline to Winston-Salem Takeoff		
Rights-Of-Way 54″ Line to Winston-Salem 18,000′		48,000
Rock Excavation 4,500 c.y. @ $10.00		45,000
Highway and Railroad Crossings		60,000
54″ Class 200 Pipe—48,000 ft. @ $17.50		2,280,000
Misc. Valves, Gates, Meters and Structures		234,900
25 M.G. Covered Reservoir and Pumping Station		825,000
Real Estate for Reservoir and Pump Station		4,200
Pumps (5-10-15) Motors and Controls—In place		153,000
Pipeline Winston-Salem Takeoff to Kernersville		
Rights-Of-Way—64,200 ft. @ $1.00		64,200
Rock Excavation—5,300 c. y. @ $10.00		53,000
Highway and Railroad Crossings		74,000
48″ Class 150 Pipe—64,200 ft. @ $31.50		2,214,900
Misc. Valves, Gates, Meters and Structures		208,500
25 M.G. Covered Reservoir at Kernersville		810,000
Real Estate for Reservoir		4,200
Sub-Total System Cost		$14,799,650
Engineering and Contingencies 15%		2,219,950
Total Estimated System Cost		$17,019,600
Use		$17,100,000
Distribution Mains		
Kernersville Reservoir to Greensboro	82,600′-42″	$ 2,613,500
Greensboro to Burlington	100,900′-20″	1,509,975
Kernersville Reservoir to High Point	63,400′-30″	1,346,200
High Point to Thomasville	31,100′-20″	478,125
Thomasville to Lexington	27,400′-16″	318,800
Sub-Total Distribution Mains		$ 6,266,600
Engineering and Contingencies 15%		939,990
Total Estimated Cost Distribution Mains		$ 7,206,590
Use		$ 7,200,000
Use Total Estimated Cost of		$24,300,000

The precedng estimate of cost for the filtered water project at the Styers Ferry site is based on a capacity of 50 m.g.d. except for the filter plant and pumping stations which would have an initial capacity of 30 m.g.d. The only increase needed to bring the over-all capacity up to 50 m.g.d. would be the addition of 20 m.g.d. capacity to the filter and pumping stations at an estimated cost of $3,500,000. Real estate estimated for the filter plant site is sufficient for the ultimate estimated capacity in the year 2000.

Comparison of Projects

The construction costs of the several projects are compared in the table below:

Raw=Water Project	Donnaha Intake	Styers Ferry Intake
Supply system	$ 9,600,000	$10,400,000
Distribution mains	530,000	600,000
Total first stage	10,130,000	11,000,000
Future additional pumps	200,000	200,000
Total 50 m.g.d. capacity	$10,330,000	$11,200,000
Filtered=Water Project		
Supply system	16,000,000	17,100,000
Distribution mains	7,200,000	7,200,000
Total first stage	23,200,000	24,300,000
Future additions to filter plant and pumping stations	3,500,000	3,500,000
Total, 50 m.g.d. capacity	$26,700,000	$27,800,000

For both raw water and filtered water the Donnaha projects would cost approximately $1,000,000 less than the Styers Ferry projects. As previously noted, the pumping head would be approximately 52 feet less at Donnaha than at Styers Ferry, and the power cost would be 15 to 20 per cent less if the Donnaha site were used. We recommend the Donnaha site as the better of the two, and have based our estimates of water costs on an intake at this site. It is possible that extended borings and design studies would show up construction difficulties at the Donnaha site, but we doubt that they would be such as to change materially the relative costs of the two projects.

9. COST OF YADKIN RIVER WATER

Raw and filtered water costs have been estimated for a Yadkin River project taking water from an intake at Donnaha. If the intake were located at Styers Ferry, the construction and operating costs would be slightly higher. Costs have been estimated for average pumpages of 10, 20, 30 and 50 m.g.d. Beyond 50 m.g.d. major additions would have to be built, and the cost would depend somewhat upon which cities had grown fastest, where the water demands were greatest, etc. A capacity of 50 m.g.d. should meet fitered-water demands until 1975 or 1980, and raw-water demands until 1990.

Interest and amortization have been calculated at 5.5 per cent of the capital cost of the works. This is equivalent to equal annual payments over a period of 30 years with interest at 3.5 + per cent. The cost figures do not include the fixed charges on the distribution mains, which are considered later in the report. Power for pumping is calculated from Duke Power Co. Schedule No. 10 for Municipal Service. Pump and motor efficiencies are taken at 80 per cent from wire to water. Filtration costs, including supervision, labor, chemicals, maintenance, and repair, are estimated to range from $18 per m.g. for a draft of 10 m.g.d. down to $12 per m.g. for drafts of 50 m.g.d.

Estimated Cost of Raw Water (**not including distribution**)

Total deficiency— m.g.d....	10	20	30	50
" " mg ann...	3,650	7,300	10,950	18,250
Average pumpage from Yadkin River m.g.d.....	5	10	10	25
Plus 25% allowance for losses, m.g.d..........	6.25	12.5	18.75	31.25
Annual pumpage— m.g....	2,280	4,550	6,850	11,400
Approximate pumpage rate —m.g.d...........	18	25	30	35
Power cost of pumping, per m.g................	$13.18	$11.39	$10.13	$9.42
Capital Cost..	$9,600,000	$9,600,000	$9,800,000	$9,800,000
Operating Costs				
Electric Power	$ 30,730	$ 51,820	$ 71,450	$ 107,390
Pump House operators....	8,000	8,000	15,000	20,000
Maintenance and repair...	5,500	8,000	10,000	15,000
Transportation	1,000	1,500	2,000	2,500
Superintendent.....	10,000	12,000	15,000	18,000
Total........	$ 55,230	$ 81,320	$ 113,450	$ 162,890
Fixed Charges @ 5.5%...	$ 528,000	$ 528,000	$ 540,000	$ 540,000
Total Annual Costs........	$ 583,230	$ 609,320	$ 653,450	$ 702,890
Average cost per m.g.....	$ 160.00	$ 83.00	$ 60.00	$ 39.00
Average cost per 100 c.f....	12.0¢	6.2¢	4.5¢	2.9¢

Note that the unit costs shown are not the costs per m.g. of water actually pumped from the Yadkin River, but rather the cost per m.g. of additional water made available by supplementing local sources with water from the Yadkin River. Thus, a raw-water deficiency of 20 m.g.d. could be met for an expediture of $626,500 per annum, or $86 per m.g.

Power cost of pumping per m.g. based on unit power cost calculated from Duke Power Company schedule number 10.

Estimated Cost of Filtered Water (not including distribution)

Average supply from Yadkin River—m.g.d.	10	20	30	50
Annual pumpage—m.g.	3,650	7,300	10,950	18,250
Power cost of pumping per m.g.	$9.68	$8.95	$9.29	$10.82
Capital cost	$16,000,000	$16,000,000	$19,500,000	$25,000,000*
Operating Costs				
Electric power	$ 35,330	$ 65,340	$ 101,730	$ 197,470
Pump house operators	16,000	18,000	19,000	20,000
Maintenance and repair	10,000	20,000	30,000	40,000
Filtration	66,000	117,000	153,000	219,000
Transportation	3,000	5,000	7,000	9,000
Superintendent	15,000	18,000	20,000	22,000
Total	$ 145,330	$ 243,340	$ 330,730	$ 507,470
Fixed charges @ 5.5%	880,000	880,000	1,075,000	1,380,000
Total annual charges	$1,025,330	$1,123,340	$1,405,730	$1,887,470
Average cost per m.g.	$ 281.00	$ 154.00	$ 128.00	$ 103.00
Average cost per 100 c.f.	21.1¢	11.6¢	9.6¢	7.7¢

* When the average consumption of filtered water from the Yadkin River reaches 50 m.g.d., peak daily requirements would be 65 m.g.d. or greater, and substantial additions would be required throughout the system. We have not estimated exactly what these would be or their cost, but the $25,000,000 total shown is sufficient to indicate the probable trend in water costs.

Power cost of pumping per m.g. based on unit power cost calculated from Duke Power Company schedule number 10.

The average costs of raw and filtered water determined in the preceding section do not include the cost of distributing water from the transmission main or Kernersville reservoir to the several cities. The booster pumping requirements would be small in all cases, and the operating costs negligible. The fixed charges on distribution mains, particularly filtered water mains, would be substantial and would affect the cost of water to each participant.

In order to estimate the cost of water to each city, it has been necessary to allocate the project costs among the participating cities. This cannot be done precisely and in the last analysis probably would be affected by how the project was financed—entirely through the sale of water, or partly through the sale of water and partly by fixed annual payments by each of the seven cities. The counties should be included also, if possible. A final determination of these matters obviously is beyond the scope of an engineering report. However, we have considered several methods and suggest the following approach.

For a raw-water project, each city would pay in proportion to its estimated water consumption in 1980 and to its estimated raw-water deficiency for that year. The percentage allocation has been calculated as follows:

	Percentage of Totals—1980		
	Water Consumption	Raw-Water Deficiency	Average
Burlington	8.9		4.45
Greensboro	30.8	45.8	38.30
High Point	15.1	27.1	21.10
Kernersville	1.1	1.6	1.35
Lexington	4.9	..	2.45
Thomasville	4.1	..	2.05
Winston-Salem	35.1	25.5	30.30
	100.0	100.0	100.0

Our estimates show that Burlington, Lexington and Thomasville will not need raw water before 1980, and that beyond that time the total requirements will be only a few million gallons per day. These relatively small additional raw-water supplies undoubtedly could be obtained locally at less cost than going to the Yadkin River at Donnaha. We cannot justify participation in a raw-water project by these three cities. If they were eliminated, the adjusted percentages would be as follows:

	Percentage of Totals 1980		
	Water Consumption	Raw-Water Deficiency	Average
Greensboro	37.6	45.8	41.70
High Point	18.4	27.1	22.75
Kernersville	1.4	1.6	1.50
Winston-Salem	42.6	25.5	34.05
	100.0	100.0	100.00

For a filtered-water project, each city would pay in proportion to its estimated water consumption in 1980, and to its estimated filtered water deficiency for that year. In this case, the percentage allocations would be as follows:

	Percentage of Totals—1980		
	Water Consumption	Filtered-Water Deficiency	Average
Burlington	8.9	2.2	5.55
Greensboro	30.8	33.3	32.05
High Point	15.1	20.3	17.70
Kernersville	1.1	0.7	0.90
Lexingtion	4.9	2.2	3.55
Thomasville	4.1	3.7	3.90
Winston-Salem	35.1	37.6	36.35
	100.0	100.0	100.00

There is more reason for Burlington, Lexington and Thomasville to participate in a filtered-water project, although costs would be relatively high. However, for comparative purposes, the allocation between the four cities most easily served would be as follows:

Percentage of Totals—1980

	Water Consumption	Filtered-Water Deficiency	Average
Greensboro........	37.6	36.1	36.85
High Point........	18.4	22.1	20.25
Kernersville.......	1.4	0.8	1.10
Winston-Salem.....	42.6	41.0	41.80
	100.0	100.0	100.00

Allocation on the basis of both total consumption and deficiency, rather than deficiency alone, is recommended. Regardless of how much water it took from the Yadkin River project, any city participating in it would derive substantial benefits from the fact that the water is available whenever the city needed it. These benefits obviously are greater for the large cities than for the small. This fact is reflected in some regional water supplies and districts by charging to each participant a share of the fixed charges calculated on the basis of total real estate valuation.

Selection of 1980 for determining percentages is somewhat arbitrary, but reflects reasonably well conditions expected within the next 20 or 30 years.

In applying the percentages to the Yadkin River project, we have assumed that fixed charges would be apportioned in accordance with the "average" percentage; operating expenses would be apportioned on the basis of water taken from the Yadkin River system. The fixed charges on each distribution main have been charged directly to the city benefited. The cost of filtered water mains serving 2 or more cities has been allocated between the cities in proportion to their "average" percentages, as indicated below.

15% of Cost of Line—Kernersville to Greensboro chargeable to Burlington

14% of Cost of Line—Kernersville to High Point chargeable to Lexington

16% of Cost of Line—Kernersville to High Point chargeable to Thomasville

52% of Cost of Line—High Point to Thomasville chargeable to Lexington

The cost of water to each of the cities is summarized in the tables following. As noted earlier, a raw-water project serving all seven cities has been eliminated because of the negligible benefits to Burlington, Lexington, and Thomasville. The raw water costs are for a 4-city project, including Greensboro, High Point, Kernersville, and Winston-Salem.

Table I

FOUR-CITY RAW WATER PROJECT

Annual and Unit Costs

Total Draft M.G.D. . .	10	20	30	50
Million Gallons per Annum . .	3,650	7,300	10,950	18,250
Fixed Charge-System . .	$ 528,000	$ 528,000	$ 540,000	$ 540,000
Total Operating Cost	$ 55,230	$ 81,320	$ 113,450	$ 162,890
GREENSBORO				
Fixed Charge-System (41.7%) .	$ 220,180	$ 220,180	$ 225,180	$ 225,180
Fixed Charge-Distrib. Main . . .	1,650	1,650	1,650	1,650
Operating Cost (45.8%)	25,300	37,240	51,960	74,600
Total	$ 247,130	$ 259,070	$ 278,790	$ 301,430
Cost per Million Gallons	$ 148.00	$ 77.00	$ 56.00	$ 36.00
Cost per 100 Cubic Feet	11.1¢	5.8¢	4.2¢	2.7¢
HIGH POINT				
Fixed Charge-System (22.75%)	$ 120,120	$ 120,120	$ 122,850	$ 122,850
Fixed Charge-Distrib. Main . . .	7,590	7,590	7,590	7,590
Operating Cost (27.1%)	14,970	22,040	30,740	44,140
Total	$ 142,680	$ 149,750	$ 161,180	$ 174,580
Cost per Million Gallons	$ 144.00	$ 76.00	$ 54.00	$ 35.00
Cost per 100 Cubic Feet	10.8¢	5.7¢	4.1¢	2.6¢
KERNERSVILLE				
Fixed Charge System (1.5%) . .	$ 7,920	$ 7,920	$ 8,100	$ 8,100
Fixed Charge-Distrib. Main . . .	2,480	2,480	2,480	2,480
Operating Cost (1.6%)	880	1,300	1,820	2,610
Total	$ 11,280	$ 11,700	$ 12,400	$ 13,190
Cost per Million Gallons	$ 193.00	$ 100.00	$ 71.00	$ 45.00
Cost per 100 Cubic Feet	14.4¢	7.5¢	5.3¢	3.4¢
WINSTON-SALEM				
Fixed Charge-System (34.05%)	$ 179,780	$ 179,780	$ 183,870	$ 183,870
Fixed Charge-Distrib. Main . . .	830	830	830	830
Operating Cost (25.5%)	14,080	20,740	28,930	41,540
Total	$ 194,690	$ 201,350	$ 213,630	$ 226,240
Cost per Million Gallons	$ 209.00	$ 108.00	$ 77.00	$ 49.00
Cost per 100 Cubic Feet	15.7¢	8.1¢	5.8¢	3.7¢

Power cost of pumping per m.g. based on unit power cost calculated from Duke Power Company schedule No. 10.

The range in raw water costs for various drafts is estimated as follows:

Draft in m.g.d.	Cost per m.g.	Cost per 100 cu. ft.
10	$144 – 209	10.8¢ to 15.7¢
20	76 – 108	5.7¢ to 8.1¢
30	54 – 77	4.1¢ to 5.8¢
50	35 – 49	2.6¢ to 3.7¢

These figures indicate that until the total draft reached 20 m.g.d., the cost of raw water would be relatively high. Thereafter, the cost would drop rapidly to low figures.

The effect of levying part of the cost against all cities regardless of the amount of water taken from the project is shown by the relatively high cost of water for Winston-Salem. As long as Winston-Salem kept its Idols plant in operation, it would require a relatively small amount from the proposed regional supply. If the Idols plant and pipeline were given up in favor of the regional supply, the unit cost of water would be less.

Table 2

SEVEN-CITY FILTERED WATER PROJECT

Annual and Unit Costs

Total Draft M.G.D.	10	20	30	50
Million Gallons per Annum	3,650	7,300	10,950	18,250
Fixed Charges–System	$ 880,000	$ 880,000	$1,075,000	$1,380,000
Total Operating Cost	$ 145,330	$ 243,340	$ 330,730	$ 507,470
BURLINGTON				
Fixed Charge–System (5.55%)	$ 48,840	$ 48,840	$ 59,660	$ 76,590
Fixed Charge–Distrib. Main	120,450	120,450	120,450	120,450
Operating Cost (2.2%)	3,200	5,350	7,280	11,160
Total	$ 172,490	$ 174,640	$ 187,390	$ 208,200
Cost per Million Gallons	$2,148.00	$1,087.00	$ 778.00	$ 519,00
Cost per 100 Cubic Feet	161.0¢	81.5¢	58.4¢	38.9¢
GREENSBORO				
Fixed Charge–System (32.05%)	$ 282,040	$ 282,040	$ 344,540	$ 442,290
Fixed Charge–Distrib. Main	140,250	140,250	140,250	140,250
Operating Cost (33.3%)	48,390	81,040	110,120	168,990
Total	$ 470,680	$ 503,330	$ 594,910	$ 751,530
Cost per Million Gallons	$ 387.00	$ 207.00	$ 163.00	$ 124.00
Cost per 100 Cubic Feet	29.0¢	15.5¢	12.2¢	9.3¢
HIGH POINT				
Fixed Charge–System (17.7%)	$ 155,760	$ 155,760	$ 190,280	$ 244,260
Fixed Charge–Distrib. Main	59,680	59,680	59,680	59,680
Operating Cost (20.3%)	29,500	49,400	67,140	103,020
Total	$ 244,940	$ 264,840	$ 317,100	$ 406,960
Cost per Million Gallons	$ 331.00	$ 179.00	$ 143.00	$ 110.00
Cost per 100 Cubic Feet	24.8¢	13.4¢	10.7¢	8.3¢

KERNERSVILLE				
Fixed Charge–System (0.9%)	$ 7,920	$ 7,920	$ 9,680	$ 12,420
Fixed Charge–Distrib. Main	.....	.....	.....	.....
Operating Cost (0.7%)	1,020	1,700	2,320	3,550
Total	$ 8,940	$ 9,620	$ 12,000	$ 15,970
Cost per Million Gallons	$ 350.00	$ 188.00	$ 157.00	$ 125.00
Cost per 100 Cubic Feet	26.2¢	14.1¢	11.8¢	9.4¢
LEXINGTON				
Fixed Charge–System (3.55%)	$ 31,240	$ 31,240	$ 38,160	$ 48,990
Fixed Charge–Distrib. Main	47,580	47,580	47,580	47,580
Operating Cost (2.2%)	3,200	5,350	7,280	11,160
Total	$ 82,020	$ 84,170	$ 93,020	$ 107,730
Cost per Million Gallons	$1,021.00	$ 524.00	$ 386.00	$ 268.00
Cost per 100 Cubic Feet	76.6¢	39.3¢	29.0¢	20.1¢
THOMASVILLE				
Fixed Charge–System (3.9%)	$ 34,320	$ 34,320	$ 41,930	$ 53,820
Fixed Charge–Distrib. Main	28,050	28,050	28,050	28,050
Operating Cost (3.7%)	5,380	9,000	12,240	18,780
Total	$ 67,750	$ 71,370	$ 82,220	$ 100,650
Cost per Million Gallons	$ 501.00	$ 264.00	$ 203.00	$ 149.00
Cost per 100 Cubic Feet	37.6¢	19.8¢	15.2¢	11.2¢
WINSTON-SALEM				
Fixed Charge–System (36.35%)	$ 319,880	$ 319,880	$ 390,760	$ 501,630
Fixed Charge–Distrib. Main	....	....	....	....
Operating Cost (37.6%)	54,640	91,500	124,350	190,810
Total	$ 374,520	$ 411,380	$ 515,110	$ 692,440
Cost per Million Gallons	$ 273.00	$ 150.00	$ 125.00	$ 101.00
Cost per 100 Cubic Feet	20.5¢	11.3¢	9.4¢	7.6¢

Power cost of pumping per m.g. based on unit power cost calculated from Duke Power Company Schedule No. 10.

For a seven cities project, the range in filtered water costs is estimated as follows:

Draft in m.g.d.	Cost per m.g.	Cost per 100 cu. ft.
10	$273 – $2148	20.5¢ to $1.61
20	150 – 1087	11.3¢ to 81.5¢
30	125 – 778	9.4¢ to 58.4¢
50	101 – 519	7.6¢ to 38.9¢

The unit costs for Greensboro, High Point, Kernersville, and Winston-Salem are fairly close, and not unreasonable for drafts of 20 m.g.d., or more. The filtered water costs for Burlington, Lexington, and Thomasville would be prohibitive until the total draft reached 30 or 40 m.g.d., largely because of the large investment in filtered water distribution mains to these three cities.

These cost figures suggest that for some years a filtered water system might have to be limited to Greensboro, High Point, Kernersville, Winston-Salem, and the area surrounding them. However, it may be desirable for the other three to participate in the formation of a regional water supply so that they may convert to it if desirable in the future. The Seven Cities Water Committee may wish to consider how such participation would be arranged.

Table 3

FOUR-CITY FILTERED WATER PROJECT

Annual and Unit Costs

Total Draft M.G.D.	10	20	30	50
Million Gallons per Annum	3,650	7,300	10,950	18,250
Fixed Charges–System	$ 880,000	$ 880,000	$1,075,000	$1,380,000
Total Operating Cost	$ 145,330	$ 243,340	$ 330,730	$ 507,470
GREENSBORO				
Fixed Charges–System (36.85%)	$ 324,280	$ 324,280	$ 396,140	$ 508,530
Fixed Charge–Distrib. Main	165,000	165,000	165,000	165,000
Operating Cost (36.1%)	52,460	87,840	119,390	183,200
Total	$ 541,740	$ 577,120	$ 680,530	$ 856,730
Cost per Million Gallons	$ 411.00	$ 219.00	$ 172.00	$ 130.00
Cost per 100 Cubic Feet	30.8¢	16.4¢	12.9¢	9.8¢
HIGH POINT				
Fixed Charge–System (20.25%)	$ 178,200	$ 178,200	$ 217,690	$ 279,450
Fixed Charge–Distrib. Main	85,250	85,250	85,250	85,250
Operating Cost (22.1%)	32,120	53,780	73,090	112,150
Total	$ 295,570	$ 317,230	$ 376,030	$ 476,850
Cost per Million Gallons	$ 366.00	$ 197.00	$ 155.00	$ 118.00
Cost per 100 Cubic Feet	27.5¢	14.8¢	11.6¢	8.9¢
KERNERSVILLE				
Fixed Charge–System (1.1%)	$ 9,680	$ 9,680	$ 11,830	$ 15,180
Fixed Charge–Distrib. Main	......	......	......	......
Operating Cost (0.8%)	1,160	1,950	2,650	4,060
Total	$ 10,840	$ 11,630	$ 14,480	$ 19,240
Cost per Million Gallons	$ 371.00	$ 199.00	$ 165.00	$ 132.00
Cost per 100 Cubic Feet	27.8¢	14.9¢	12.4¢	9.9¢
WINSTON-SALEM				
Fixed Charge–System (41.8%)	$ 367,840	$ 367,840	$ 449,350	$ 576,840
Fixed Charge–Distrib. Main	....	....	....	....
Operating Cost (41.0%)	59,590	99,770	135,600	208,060
Total	$ 427,430	$ 467,610	$ 584,950	$ 784,900
Cost per Million Gallons	$ 286.00	$ 156.00	$ 130.00	$ 105.00
Cost per 100 Cubic Feet	21.5¢	11.7¢	9.8¢	7.9¢

Power cost of pumping per m.g. based on unit power cost calculated from Duke Power Company schedule No. 10.

For a four-city filtered water project, some of the long distribution mains would be eliminated, and the unit cost of water to the participants would be fairly uniform. The range in costs for various drafts would be as follows:

Draft in m.g.d.	Cost per m.g.	Cost per 100 cu. ft.
10	$286 – 411	21.5¢ to 30.8¢
20	156 – 219	11.7¢ to 16.4¢
30	130 – 172	9.8¢ to 12.9¢
50	105 – 132	7.9¢ to 9.9¢

With this project Winston-Salem would pay the lowest unit price; Greensboro would pay the highest, principally because of the long filtered water distribution main between the Kernersville Reservoir and Greensboro.

In figuring the cost of water for a Four-City Filtered Water Project the distribution mains from Kernersville to Greenboro and to High Point have not been reduced in size. If Burlington should wish to retain its 15% interest in the main from Kernersville to Greensboro, the annual charge which Burlington should pay would be $24,750. The fixed charge for the distribution main for Greensboro would then be reduced by this amount.

If Thomasville should wish to retain its 16% interest in the main from Kernersville to High Point, the annual charge which Thomasville should pay would be $13,640. If Lexington should wish to retain its 14% interest in the main from Kernersville to High Point, the annual charge which Lexington should pay would be $11,935. The fixed charge for the distribution main for High Point would then be reduced by either or both of the above amounts.

If none of the above three cities should wish to retain their interest in the distribution mains from Kernersville, then the mains to Greensboro and to High Point could be reduced in size. The lower construction cost would be reflected in reduced annual charges.

Filtered-Water System Vs. Raw-Water System

The filtered-water system would cost about twice as much to build as the raw-water system, and the unit costs of filtered-water delivered to the cities would be proportionately greater. This is natural since if the raw-water system were built, each community would have to undertake on its own, the pumping, transmission and filtering of the raw water. However, a filtered-water system from the Yadkin River would be much the better for a number of reasons:

(a) With a filtered-water system no further expansion of local works would be needed, except perhaps the installation of distribution reservoirs and booster pumps. With a raw-water system, each city would have to maintain and enlarge its present facilities from time to time to keep up with growing demands.

(b) Yadkin River water would be available not only in the cities but also along the transmission and distribution mains in the rural areas between the cities. The availability of an adequate water supply unquestionably would encourage the development of these areas. Sale of water in these areas would help finance the project.

(c) The filtered water would be delivered directly to the several distribution systems, usually at points removed from the existing filter plant and pumping station. This would have the effect of providing a second source of filtered water for each distribution system and would reduce substantially the cost of reinforcing the distribution system in years to come.

(d) Some of the cities are faced with the construction of additional filter plant capacity within the next few years. If a regional filtered-water system were built promptly, these local expenditures could be avoided.

Appendix A

Detailed data for each of the seven cities and each of the four counties, including records of past population growth and estimated future population for each decade follow.

BURLINGTON, N. C.

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1910	4,808		
1920	5,952	23.8	2.16
1930	9,737	63.6	5.05
1940	12,198	25.3	2.28
1950	24,560	102.2	7.24
1956*	28,482	15.97	2.50

Total Increase 1910-1950—410.8%

Average Annual Increase 1910-1950—4.16%

Estimated Future Growth

1960	31,438	10.38	2.50
1970	40,240	28.01	2.50
1980	49,053	21.90	2.0
1990	59,796	21.90	2.0
2000	72,891	21.90	2.0

Total Estimated Increase 1950-2000—196.8%

GREENSBORO, N. C.

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1910	15,895		
1920	19,861	25.0	2.26
1930	53,569	169.7	10.42
1940	59,319	10.7	1.02
1950	74,389	25.4	2.30
1956*	92,000	23.7	2.16

Total Increase 1919-1950—368%

Average Annual Increase 1910-1950—3.94%

Estimated Future Growth

1960	103,546	12.55	3.0
1970	139,155	34.39	3.0
1980	169,630	21.90	2.0
1990	206,779	21.90	2.0
2000	252,064	21.90	2.0

Total Estimated Increase 1950-2000—238.8%

HIGH POINT, N. C.

Past Growth

1910	9,525		
1920	14,302	50.2	4.15
1930	36,745	156.9	9.89
1940	38,495	4.8	0.47
1950	39,973	3.8	0.37
1956*	45,000	12.6	1.17

Total Increase 1910-1950—319.7%

Average Annual Increase 1910-1950—3.65%

Estimated Future Growth

1960	50,648	12.55	3.0
1970	68,066	34.39	3.0
1980	82,972	21.90	2.0
1990	101,143	21.90	2.0
2000	123,293	21.90	2.0

Total Estimated Increase 1950-2000—208.4%

*Estimated

KERNERSVILLE, N. C.

Past Growth

1910	1,128		
1920	1,219	8.1	0.88
1930	1,754	43.9	3.72
1940	2,103	19.9	1.84
1950	2,396	13.9	1.34
1956*	2,860	19.4	3.0

Total Increase 1910-1950—112.4%

Average Annual Increase 1910-1950—1.88%

Estimated Future Growth

1960	3,220	12.55	3.0
1970	4,327	34.39	3.0
1980	5,275	21.90	2.0
1990	6,430	21.90	2.0
2000	7,838	21.90	2.0

Total Estimated Increase 1950-2000—227.1%

*Estimated

LEXINGTON, N. C.

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1910	4,163		
1920	5,254	26.2	2.36
1930	9,652	83.7	6.27
1940	10,050	4.0	0.39
1950	13,571	35.0	3.05
1956*	15,738	15.97	2.50

Total Increase 1910-1950—226.0%

Average Annual Increase 1910-1950—3.00%

Estimated Future Growth

1960	17,372	10.38	2.50
1970	22,238	28.01	2.50
1980	27,108	21.90	2.0
1990	33,045	21.90	2.0
2000	40,282	21.90	2.0

Total Estimated Increase 1950-2000—196.8%

WINSTON-SALEM, N. C.

Past Growth

1910	22,700		
1920	48,395	113.2	7.87
1930	75,274	55.5	4.53
1940	79,815	6.0	0.59
1950	87,811	10.0	0.97
1956*	104,847	19.4	3.0

Total Increase 1910-1950—286.8%

Average Annual Increase 1910-1950—3.44%

Estimated Future Growth

1960	118,005	12.55	3.0
1970	158,587	34.39	3.0
1980	193,318	21.90	2.0
1990	235,655	21.90	2.0
2000	287,263	21.90	2.0

Total Estimated Increase 1950-2000—227.1%

*Estimated

THOMASVILLE, N. C.

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1910	3,877		
1920	5,676	46.4	3.88
1930	10,090	77.7	5.92
1940	11,041	9.4	0.90
1950	11,154	1.02	0.10
1956*	12,935	15.97	2.50

Total Increase 1910-1950—187.69%

Average Annual Increase 1910-1950—2.68%

Estimated Future Growth

1960	14,278	10.38	2.50
1970	18,277	28,01	2.50
1980	22,280	21.90	2.0
1990	27,159	21.90	2.0
2000	33,107	21.90	2.0

Total Estimated Increase 1950-2000—196.8%

*Estimated

ALAMANCE COUNTY—LAND AREA 434 SQUARE MILES

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1900	25,665		
1910	28,712	11.9	1.13
1920	32,718	14.0	1.32
1930	42,140	28.8	2.57
1940	57,427	36.3	3.14
1950	71,220	24.0	2.18
1956*	80,123	12.5	2.00

Total Increase 1900-1950—177.5%
Average Annual Increase
1900-1950—2.06%

Estimated Future Growth

1960	86,693	8.2	2.0
1970	105,679	21.9	2.0
1980	128,823	21.9	2.0
1990	157,035	21.9	2.0
2000	191,426	21.9	2.0

Total Estimated Increase
1950-2000—168.8%

DAVIDSON COUNTY—LAND AREA 548 SQUARE MILES

Past Growth

1900	23,403		
1910	29,404	25.6	2.31
1920	35,201	19.7	1.83
1930	47,865	36.0	3.12
1940	53,377	11.5	1.10
1950	62,244	16.6	1.55
1956*	70,002	12.5	2.0

Total Increase 1900-1950—166.0%
Average Annual Increase
1900-1950—1.98%

Estimated Future Growth

1960	75,742	8.2	2.0
1970	92,329	21.9	2.0
1980	112,549	21.9	2.0
1990	137,197	21.9	2.0
2000	167,243	21.9	2.0

Total Estimated Increase
1950-2000—168.7%

*Estimated

GUILFORD COUNTY—LAND AREA 651 SQUARE MILES

Past Growth		Per Cent Increase	
Year	Population	Total	Annual
1900	39,074		
1910	60,497	54.8	4.47
1920	79,272	31.0	2.74
1930	133,010	67.8	5.31
1940	158,916	19.5	1.80
1950	191,057	20.2	1.86
1956*	228,122	19.4	3.0

Total Increase 1900-1950—388.9%
Average Annual Increase
1900-1950—3.22%

Estimated Future Growth

1960	256,637	12.5	3.0
1970	312,840	21.9	2.0
1980	381,352	21.9	2.0
1990	464,868	21.9	2.0
2000	566,674	21.9	2.0

Total Estimated Increase
1950-2000—196.6%

FORSYTH COUNTY—LAND AREA 424 SQUARE MILES

Past Growth

1900	35,261		
1910	47,311	34.2	3.00
1920	77,269	63.3	5.04
1930	111,681	44.5	3.76
1940	125,475	12.4	1.15
1950	146,135	16.5	1.54
1956*	174,485	19.4	3.00

Total Increase 1900-1950—314.4%
Average Annual Increase
1900-1950—2.89%

Estimated Future Growth

1960	196,296	12.5	3.00
1970	239,285	21.9	2.00
1980	291,688	21.9	2.00
1990	355,568	21.9	2.00
2000	433,437	21.9	2.00

Total Estimated Increase
1950-2000—196.6%

*Estimated

Detailed records of past consumption and estimate of future needs for each of the seven cities follow.

BURLINGTON, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Annual	Max. 3 Days
1944	1.9			
1946	2.5	31.6	14.70	3.15
1948	2.8	12.0	5.84	3.72
1950	3.5	25.0	11.80	4.27
1952	3.6	2.9	1.44	5.20
1954	4.2	16.7	8.03	5.40
1956*	4.65	10.71	5.22	5.95

Total Increase 1944-1956—144.7%

Average Annual Increase 1944-1956—7.74%

*Estimated

Estimated Future Consumption

1960	*5.19	11.6	2.78	7.00
1970	*6.70	29.1	2.59	9.05
1980	8.34	24.5	2.22	11.26
1990	11.06	32.6	2.86	14.93
2000	14.58	31.8	2.80	19.68

*Burlington is now using 165 gpc per day. We have estimated 165 gpc per day for estimating consumption in 1960 and 1970.

GREENSBORO, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Annual	Max. 3 Days
1926	3.71			5.30
1930	4.01	8.1	0.77	5.38
1940	5.18	29.2	2.59	6.69
1950	9.07	75.2	5.76	11.01
1956*	9.98	10.0	0.96	13.49

Total Increase 1926-1956—169%

Average Annual Increase 1926-1956—3.37%

*Estimated

Estimated Future Consumption

1960	14.50	45.3	9.79	19.58
1970	21.57	48.8	4.06	29.12
1980	28.84	33.7	2.94	38.93
1990	38.25	32.6	2.86	51.64
2000	50.41	31.8	2.80	68.05

HIGH POINT, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Annual	Max. 3 Days
1926	2.07			2.89
1930	2.41	16.1	3.87	3.73
1940	3.24	34.4	3.01	4.20
1950	4.69	44.7	3.78	6.00
1956*	5.39	14.9	2.35	7.26

Total Increase 1926-1956 160%

Average Annual Increase 1926-1956 3.25%

*Estimated

Estimated Future Consumption

1960	7.09	31.5	7.08	9.57
1970	10.55	48.8	4.06	14.24
1980	14.11	33.7	2.94	19.05
1990	18.71	32.6	2.86	25.26
2000	24.66	31.8	2.80	33.29

KERNERSVILLE, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Annual	Max. 3 Days
1946	.171			
1948	.302	76.6	32.90	76.6
1950	.283	− 6.7	.....	.418
1952	.323	14.1	6.82	.432
1954	.373	15.5	7.46	.540
1956*	.578	55.0	24.5	.660

Total Increase 1946-1956--338%

Average Annual Increase 1946-1956--12.95%

*Estimated

Estimated Future Consumption

1960	.64	10.7	2.58	.86
1970	.86	34.4	3.00	1.16
1980	1.05	22.1	2.02	1.41
1990	1.28	21.9	2.00	1.72
2000	1.66	29.7	2.64	2.24

Kernersville is now using 207 gpc per day and we have 200 in Estimated Future Consumption.

LEXINGTON, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Per Cent Increase Annual	Max. 3 Days
1946	1.64			1.98
1948	1.85	12.8	6.20	2.45
1950	1.83	− 1.1*	....	2.40
1952	2.03	10.9	5.31	2.85
1954	1.80	−12.8*	....	2.53
1956**	2.00	11.1	5.41	2.96

Total Increase 1946-1956—21.95%

Average Annual Increase 1946-1956—2.02%

*Decrease assumed to be due to short supply.

**Estimated

Estimated Future Consumption

1960	2.43	21.5	4.99	3.28
1970	3.45	42.0	3.57	4.66
1980	4.61	33.6	2.94	6.22
1990	6.11	32.5	2.86	8.25
2000	8.06	31.9	2.81	10.88

THOMASVILLE, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Per Cent Increase Annual	Max. 3 Days
1940	.58			
1945	.74	27.6	5.00	1.00
1950	1.00	35.1	6.20	1.35
1952	1.05	5.0	2.47	1.48
1954	1.22	16.2	7.75	1.80
1956*	1.30	6.6	3.25	1.80

Total Increase 1940-1956—124.1%

Average Annual Increase 1940-1956—5.12%

*Estimated

Estimated Future Consumption

1960	2.00	53.8	11.40	2.70
1970	2.83	41.5	3.54	3.82
1980	3.79	33.9	2.96	5.12
1990	5.02	32.5	2.86	6.78
2000	6.62	31.9	2.81	8.94

Appendix B Continued

WINSTON SALEM, N. C.

Past Consumption

Year	Average Annual Daily Consump.	Per Cent Increase Total	Annual	Max. 3 Days
1920	4.57			
1930	7.19	57.3	1.64	
1940	7.69	7.0	0.68	9.29
1950*	10.11	31.5	2.78	13.81
1956*	14.64	41.8**	6.38	19.56

Total Increase 1920-1956 320%

Average Annual Increase 1920-1956 3.30%

*(Fiscal)

**New Supply in 1950

Estimated Future Consumption

1960	16.52	12.8	3.06	22.30
1970	24.58	48.8	4.06	33.18
1980	32.86	33.7	2.91	44.36
1990	43.60	32.7	2.86	58.86
2000	57.45	31.8	2.80	77.56

AVERAGE WATER CONSUMPTION, GPCD, PAST AND ESTIMATED FUTURE BY WATER WORKS SUPERINTENDENTS

City and State	1936	1946	1956	1966	1976
New York, N. Y.	134	146	138	153	162
Baltimore, Md.	131	150	159	174	188
Philadelphia, Pa.	...	163	171	180	188
Springfield, Mass.	100	127	175	230	278
Hartford, Conn.	80	100	111	122	134
Charlotte, N. C.	79	96	109	144	178
Lynchburg, Va.	83	95	114	134	156
Raleigh, N. C.	..	82	102	120	136
Baton Rouge, La.	88	89	85	93	102
Atlanta, Ga.	99	115	122	130	138
Buffalo, N. Y.	210	214	242	...	...
Toledo, Ohio	123	127	149	169	171
Akron, Ohio	91	120	138	150	162
Cedar Rapids, Ia.	..	91	136	170	200
Madison, Wisc.	110	135	150	160	175
Des Moines, Ia.	100	100	114	117	125
Omaha, Nebr.	140	156	181	190	207
Wichita, Kans.	93	117	146	148	160
Oklahoma City, Okla.	79	82	114	154	183
Dallas, Texas	100	116	143	158	175
Austin, Texas	99	122	140	140	138
Sacramento, Calif.	210	258	236	240	250
Oakland, Calif.	72	102	130	159	177
Portland, Ore. (Water Auth.)	97	114	104	115	120
San Diego Co., Calif.	..	162	180	190	190
San Diego, Calif.	114	139	126	140	145
Salem, Ore.	...	139	156	207	224

Reference-Public Works Magazine, December 1956.

Appendix C Continued

MAXIMUM PER CAPITAL PER DAY WATER USE, PAST AND ESTIMATED FUTURE, BY WATER WORKS SUPERINTENDENTS

City and State	1936	1946	1956	1966	1976
New York, N. Y.	182	174	172	190	200
Baltimore, Md.	...	171	206	243	271
Philadelphia, Pa.	...	195	221	230	240
Springfield, Mass.	135	195	285	284	308
Hartford, Conn.	106	132	161	177	194
Charlotte, N. C.	103	132	157	195	243
Lynchburg, Va.	118	126	152	190	225
Raleigh, N. C.	...	89	153	179	206
Baton Rouge, La.	114	115	112	123	135
Atlanta, Ga.	128	145	170	189	208
Buffalo, N. Y.	286	287	243	...	...
Toledo, Ohio	185	179	235	264	267
Akron, Ohio	147	157	197	217	244
Cedar Rapids, Ia.	...	...	230	280	320
Madison, Wisc.	220	250	300	320	350
Des Moines, Ia.	161	142	184	200	215
Omaha, Nebr.	254	264	428	440	440
Wichita, Kans.	175	219	292	317	320
Oklahoma City, Okla.	137	167	221	321	383
Dallas, Texas	194	226	277	306	340
Austin, Texas	237	237	312	275	276
Sacramento, Calif.	358	436	424	440	450
Oakland, Calif.	108	174	200	247	267
Portland, Ore.	179	243	237	245	250
San Diego, Calif.	176	191	199	210	220
Salem, Ore.	...	340	385	450	475

Reference-Public Works Magazine, December 1956.

ESTIMATED DIVERSION OF YADKIN RIVER WATER FOR GREENSBORO

	For Average Draft of 30 mgd			For Average Draft of 40 mgd		
	Plan A	Plan B	Plan C	Plan A	Plan B	Plan C
Annual Water Consumption—m.g.	10,950	10,950	10,950	14,600	14,600	14,600
Available Locally—m.g.	6,350	9,080	10,020	6,350	10,120	12,860
Balance From Yadkin River	4,600	1,870	930	8,250	4,480	1,740
Average Annual Rate of Pumping						
From Local Source—m.g.d.	17.4*	24.9	27.5	17.4*	27.7	35.2
From Yadkin River—m.g.d.	12.6	5.1	2.5	22.6	12.3	4.8
Ratio—Annual Pumpage from Yadkin River	100%	40%	20%	100%	54%	21%
Average Number of Days Per Year Pumping From Yadkin River would be needed	365	147	31	365	195	68
Pumping Rate From Yadkin River–m.g.d.	12.6	12.6	30.	22.6	22.6	40.
Capacity of Pumping Station and Filter Plant Needed at Greensboro, Without Allowances for Peak Day Requirements	17.4	30.	30.	17.4	40.	40.

NOTE: No allowances made for variations in daily demands. Actual diversions likely to be somewhat higher because of relatively greater water use during dry seasons.

PLAN A – Filtered water from Yadkin River to meet all demands above 17.4 mgd; local supply operated at 17.4 mgd, the estimated safe yield; no increase in Greensboro filter plant needed.

PLAN B – Raw water from Yadkin pumped into reservoir during summer and fall months when natural runoff is less than total demand. Pumping from Yadkin started early and continued at low daily rate until natural reservoir inflow exceeds total demand. Greensboro filter plant capacity would have to be increased to take care of total demand—30 or 40 m.g.d.

PLAN C – Raw water from Yadkin (or filtered water from Yadkin) but not until local reservoirs were depleted. Pumping rate from Yadkin would then equal total demand. Increased filter plant capacities needed at Greensboro.

*Estimated safe yield of Hamburg-Brandt without raising Lake Brandt but with 4-foot flashboards on Hamburg Lake spillway. Analysis not corrected for revised yield data used in report; they would not change conclusions appreciably.

The pumping requirements under three separate operating plans are presented:

Plan A applies to filtered water from the Yadkin River. Under this plan the water obtained locally would be limited to the safe dry-weather yield of the source. In a year the local supply would total 365 x 17.4 m.g.d. = 6,350. The Yadkin River supply would be used continuously to make up the difference between the total demand and local supply. Plan A would require the greatest amount of water from the Yadkin River.

Plan C applies to raw water from the Yadkin River. Under this plan the local water supplies would be used to meet all demands until the local reservoirs were depleted. Thereafter, the Yadkin River supply would be used until rains and increased runoff provided enough water in the local reservoirs. Plan C would require the least possible total water from the Yadkin River, but when the water was needed, it would have to be pumped at relatively high rates. Full realization of Plan C would be practically impossible, since no prudent operator would be willing to empty his local reservoir before turning to the auxiliary supply.

Plan B is a compromise between Plans A and C, and is the one most likely to be used if a raw-water project from the Yadkin River were built. Under Plan B the local reservoirs would be kept substantially full by pumping water into them from the Yadkin River during the dry months when the demand exceeded the natural flow in the local streams. The only objection to Plan B is that the operator cannot foretell when it will rain and whether or not pumping from the Yadkin River will be necessary, and to be on the safe side there is bound to be some unnecessary pumping. During a heavy local storm, the reservoirs fill naturally in any event, and the money spent on pumping up to that time may be wasted.

The percentage of water obtained locally and from the Yadkin River under Plans A and B is summarized below:

	PLAN A (Filtered Water)		PLAN B (Raw Water)	
	Local	Yadkin R.	Local	Yadkin R.
For average draft of 30 m.g.d...	58%	42%	83%	17%
For average draft of 40 m.g.d...	43%	57%	69%	31%

For a total draft of 30 m.g.d. in Greensboro, the quantity of raw water required from the Yadkin River would be 40 per cent of the filtered water needs (17% ÷ 42%); for a demand of 40 m.g.d., the ratio would increase to 55%. A figure of 50 per cent can be used safely. For much larger quantities the local supply would become less and less important and the raw water pumpage would approach more nearly the filtered water requirement.

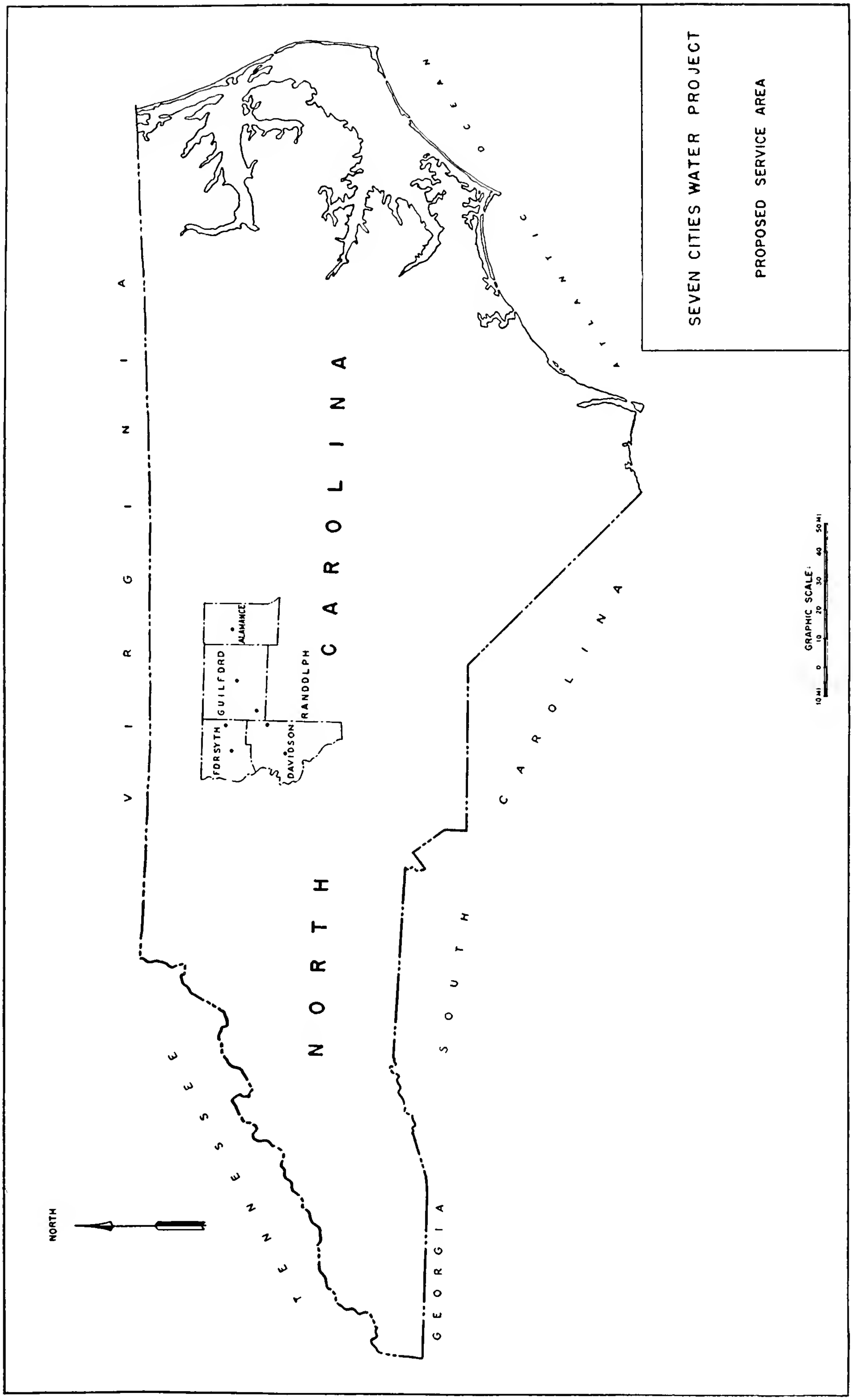
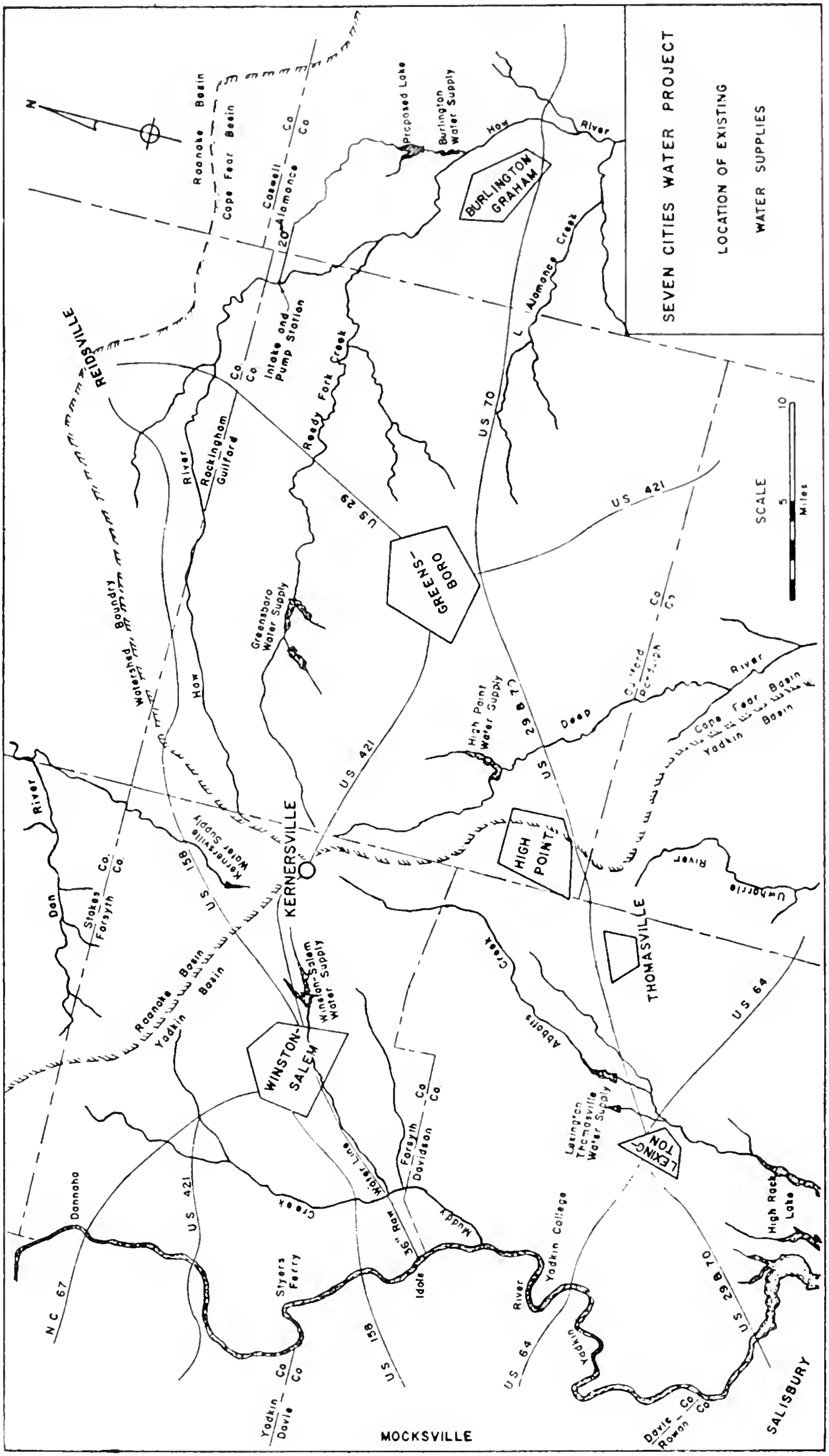
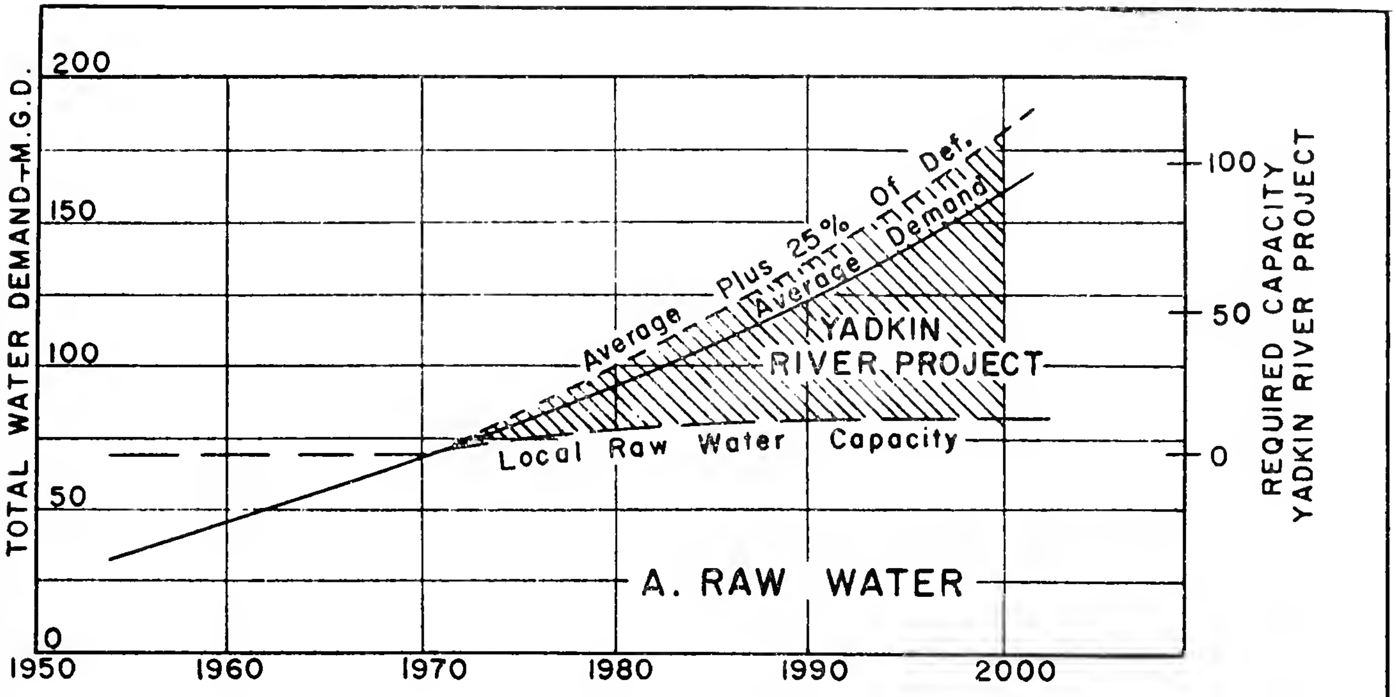
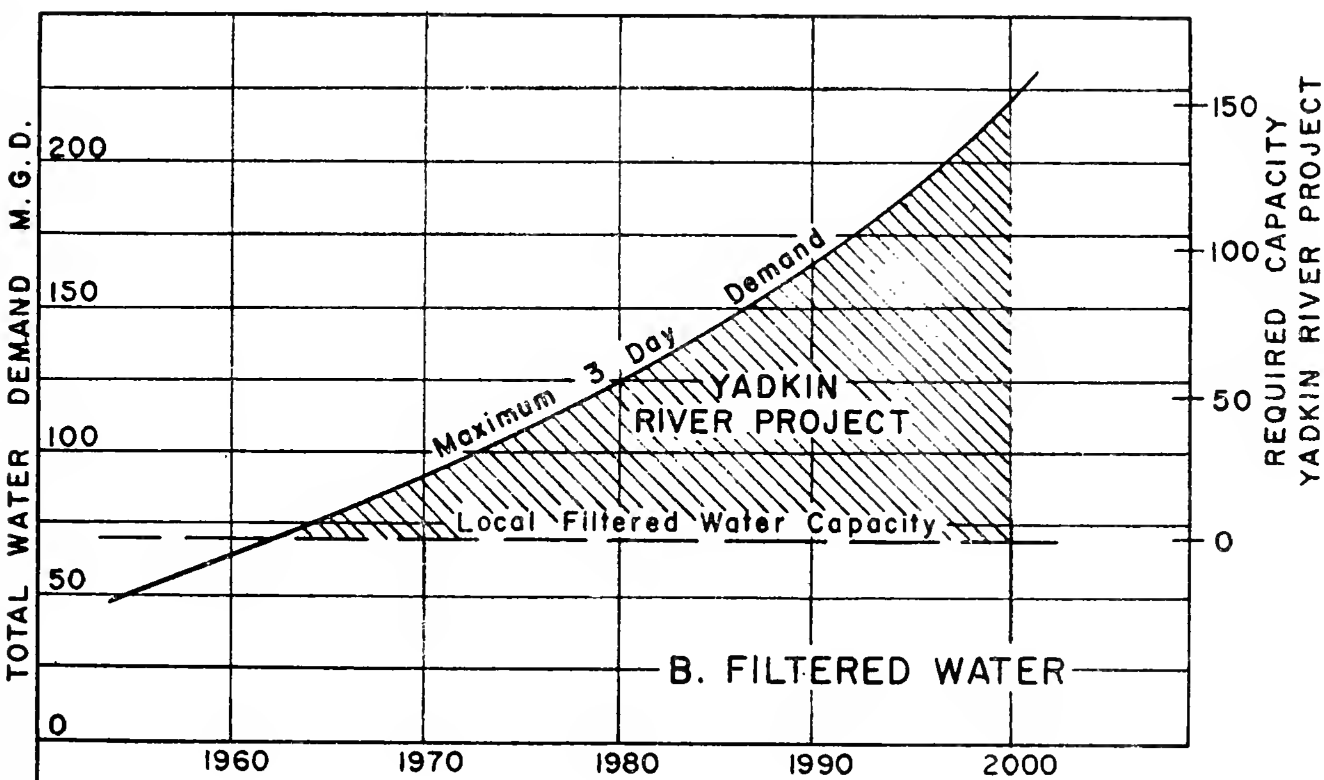

SEVEN CITIES WATER PROJECT
PROPOSED SERVICE AREA
V I R G I N I A
N O R T H C A R O L I N A
S O U T H C A R O L I N A
T E N N E S S E E
G E O R G I A
A T L A N T I C O C E A N
ALAMANCE
GUILFORD
RANDOLPH
FORSYTH
DAVIDSON
NORTH
GRAPHIC SCALE:
10 MI 0 10 20 30 40 50 MI

EXHIBIT 2


SEVEN CITIES WATER PROJECT
LOCATION OF EXISTING
WATER SUPPLIES
SCALE
Miles
REIDSVILLE
BURLINGTON GRAHAM
GREENSBORO
KERNERSVILLE
HIGH POINT
THOMASVILLE
WINSTON-SALEM
LEXINGTON
SALISBURY
MOCKSVILLE
Proposed Lake
Burlington Water Supply
Greensboro Water Supply
High Point Water Supply
Kernersville Water Supply
Winston-Salem Water Supply
Lexington Thomasville Water Supply
Intake and Pump Station
High Rock Lake
Reedy Fork Creek
Alamance Creek
Haw River
Deep River
Dan River
Yadkin River
Uwharrie River
Abbotts Creek
Muddy Creek
Roanoke Basin
Cape Fear Basin
Yadkin Basin
Watershed Boundry
Water Line
US 29
US 70
US 421
US 158
US 64
US 29 & 70
NC 67
Stokes Co
Forsyth Co
Caswell Co
Alamance Co
Rockingham Co
Guilford Co
Forsyth Co
Davidson Co
Yadkin Co
Davie Co
Rowan Co
Dannaha
Styers Ferry
Idols
Yadkin College





SEVEN CITIES WATER PROJECT

ESTIMATED FUTURE

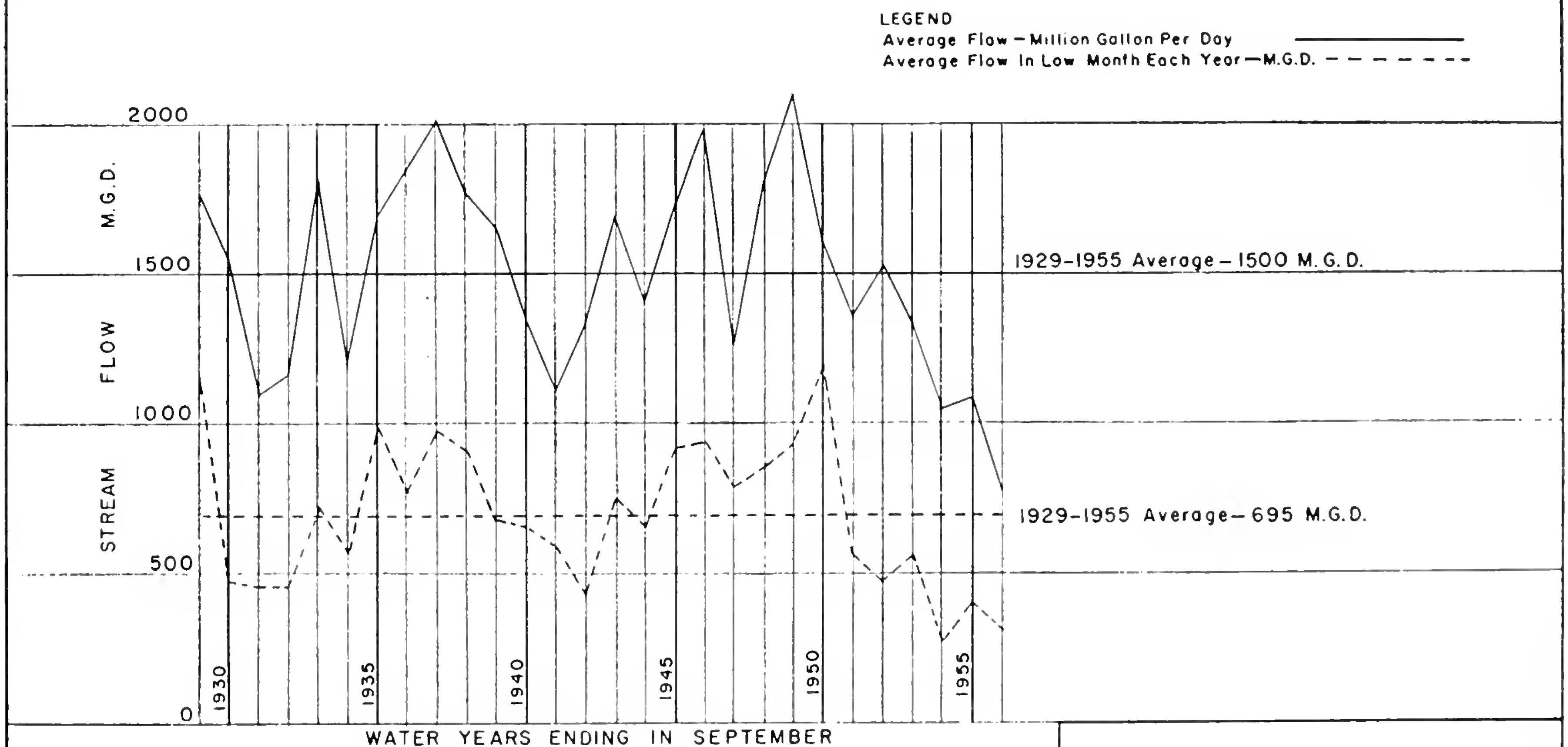
WATER REQUIREMENTS

EXHIBIT 4

STREAM FLOW YADKIN RIVER AT STYER'S FERRY

DRAINAGE AREA 1870 SQ. MILES

BASED ON FLOWS AT YADKIN COLLEGE (D.A. 2280 S.M.)



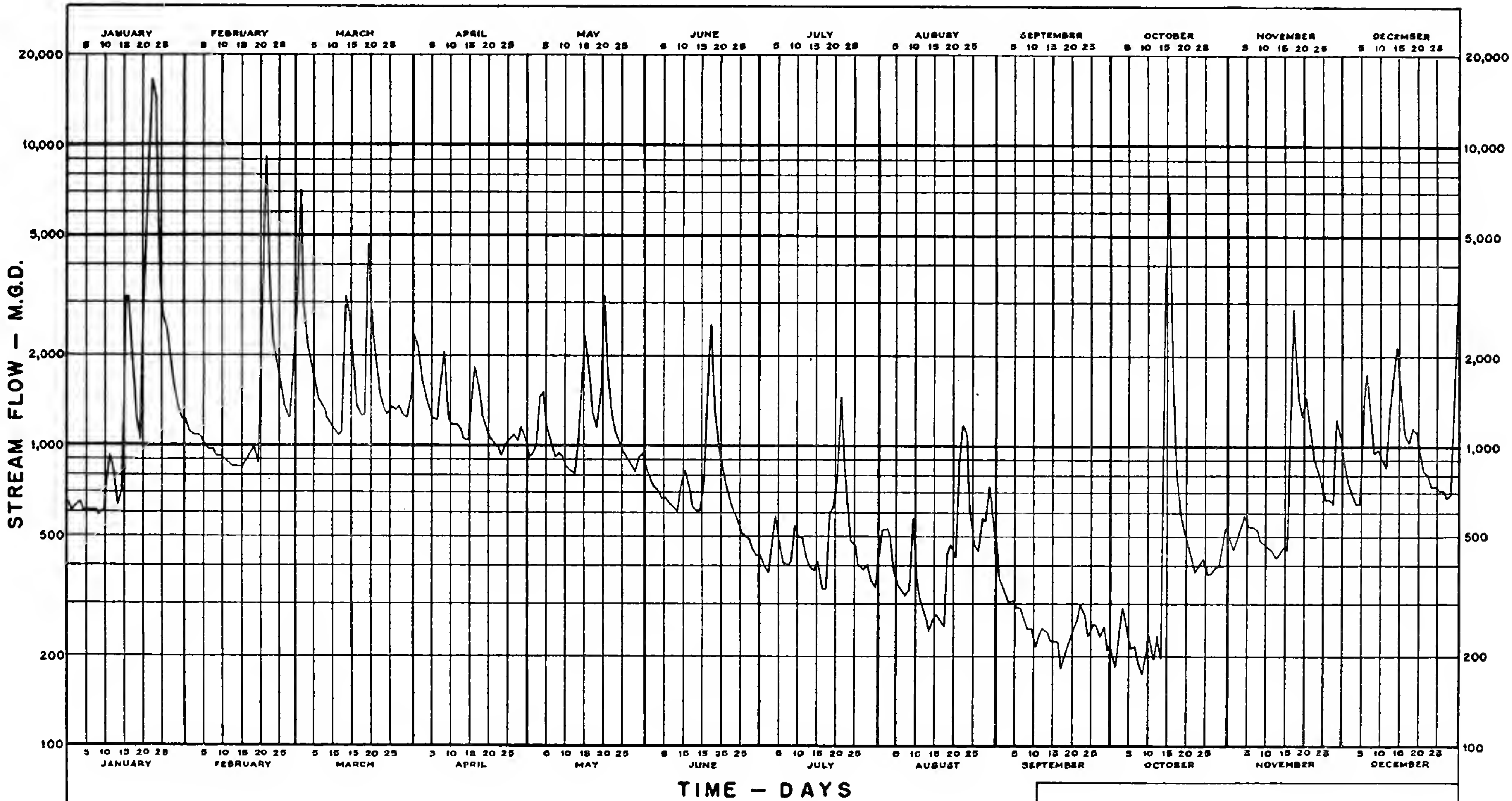
NOTE
MAXIMUM DAILY FLOW 46,025 M.G.D. JULY, 1916
MINIMUM DAILY FLOW 175 M.G.D. OCT. 9, 1954 & SEPT. 23, 1956

SEVEN CITIES WATER PROJECT

ANNUAL FLOWS

YADKIN RIVER AT STYERS FERRY

1929–1955



DAILY FLOW OF YADKIN RIVER AT STYER'S FERRY FOR 1954

DRAINAGE AREA 1870 SQ. MILES

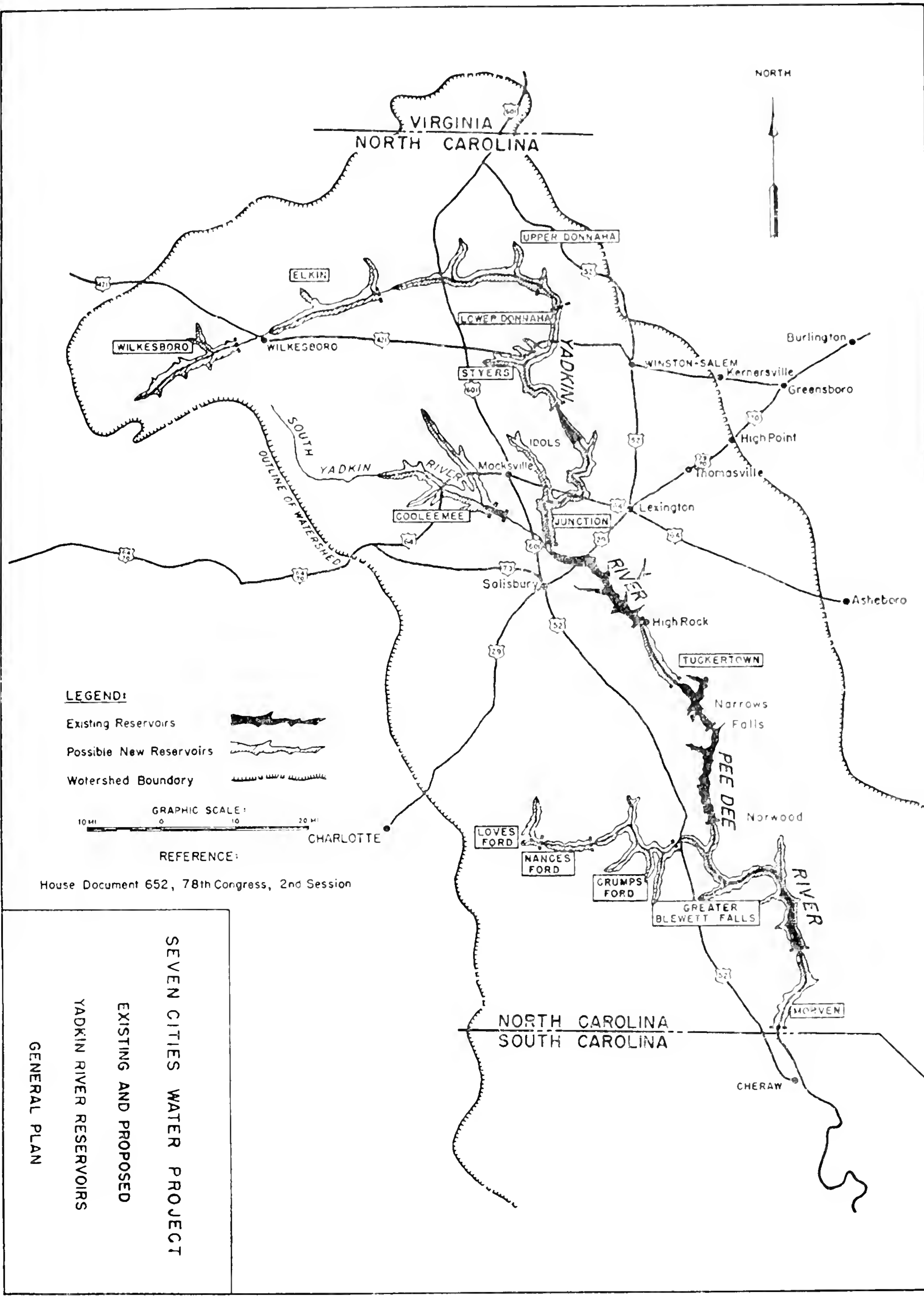
SEVEN CITIES WATER PROJECT

DAILY FLOWS

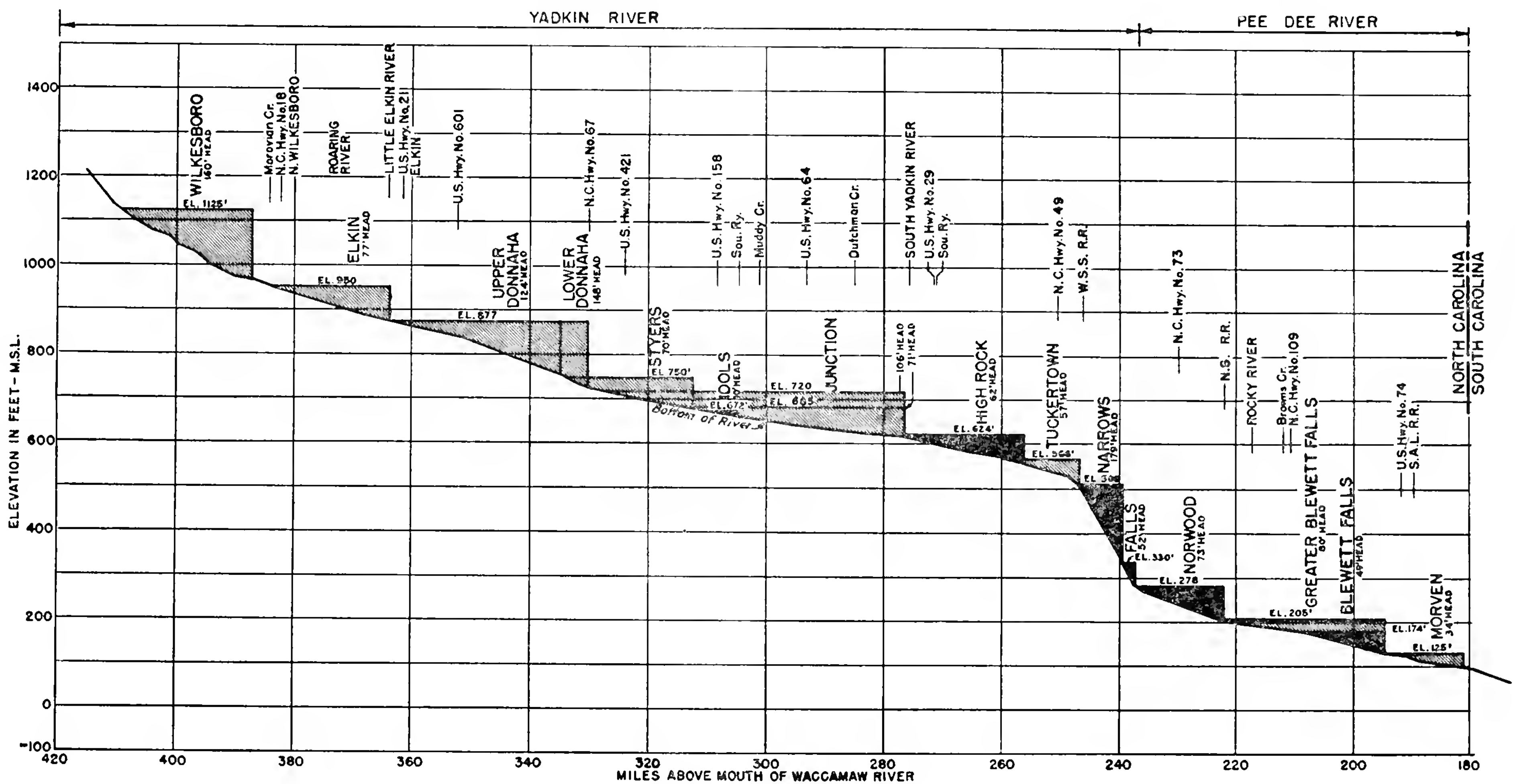
YADKIN RIVER AT STYERS FERRY

1954

EXHIBIT 6



VIRGINIA
NORTH CAROLINA
NORTH
UPPER DONNAHA
ELKIN
LOWER DONNAHA
WILKESBORO
WILKESBORO
STYERS
YADKIN
Burlington
WINSTON-SALEM
Kernersville
Greensboro
High Point
Thomasville
SOUTH YADKIN RIVER
IDOLS
Mocksville
COOLEEMEE
JUNCTION
Lexington
OUTLINE OF WATERSHED
Salisbury
RIVER
Asheboro
High Rock
TUCKERTOWN
Narrows
Falls
PEE DEE
Norwood
LEGEND:
Existing Reservoirs
Possible New Reservoirs
Watershed Boundary
GRAPHIC SCALE:
10 MI
0
10
20 MI
CHARLOTTE
REFERENCE:
House Document 652, 78th Congress, 2nd Session
LOVES FORD
NANCES FORD
CRUMPS FORD
GREATER BLEWETT FALLS
RIVER
MORVEN
NORTH CAROLINA
SOUTH CAROLINA
CHERAW
SEVEN CITIES WATER PROJECT
EXISTING AND PROPOSED
YADKIN RIVER RESERVOIRS
GENERAL PLAN



YADKIN – PEE DEE RIVER

REFFERENCE: House Document 652, 78th Congress, 2nd Session

LEGEND:

Existing Reservoir

Proposed Reservoir

NOTE:

Reservoirs are shown at full pool

Heads shown are gross heads

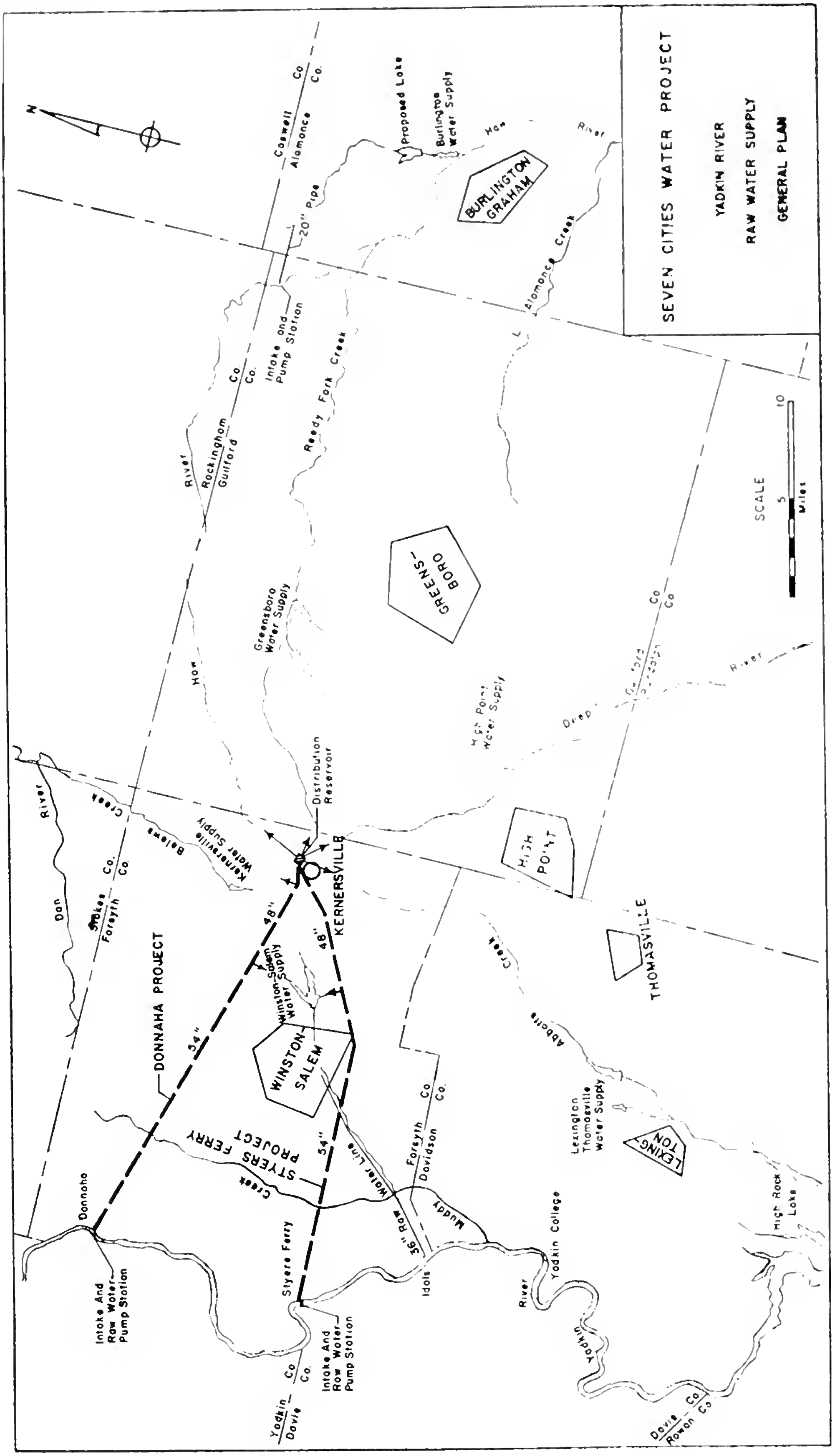
SEVEN CITIES WATER PROJECT

EXISTING AND PROPOSED

YADKIN RIVER RESERVOIRS

PROFILE

EXHIBIT 8


SEVEN CITIES WATER PROJECT
YADKIN RIVER
RAW WATER SUPPLY
GENERAL PLAN
SCALE
0
5
10
Miles
N
BURLINGTON GRAHAM
GREENS-BORO
HIGH POINT
THOMASVILLE
LEXING-TON
WINSTON-SALEM
KERNERSVILLE
DONNAHA PROJECT
STYERS FERRY PROJECT
Caswell Co.
Alamance Co.
Rockingham Co.
Guilford Co.
Stokes Co.
Forsyth Co.
Forsyth Co.
Davidson Co.
Yadkin Co.
Davie Co.
Davie Co.
Rowan Co.
Proposed Lake
Burlington Water Supply
Haw River
Alamance Creek
20" Pipe
Intake and Pump Station
Reedy Fork Creek
Greensboro Water Supply
Haw River
High Point Water Supply
Deep River
Distribution Reservoir
Dan River
Belews Creek
Kernersville Water Supply
48"
48"
54"
54"
Winston-Salem Water Supply
Water Line
36" Raw
Muddy Creek
Creek
Abbotts Creek
Lexington Thomasville Water Supply
High Rock Lake
Donnaha
Intake And Raw Water Pump Station
Styers Ferry
Intake And Raw Water Pump Station
Idols
Yadkin College
Yadkin River

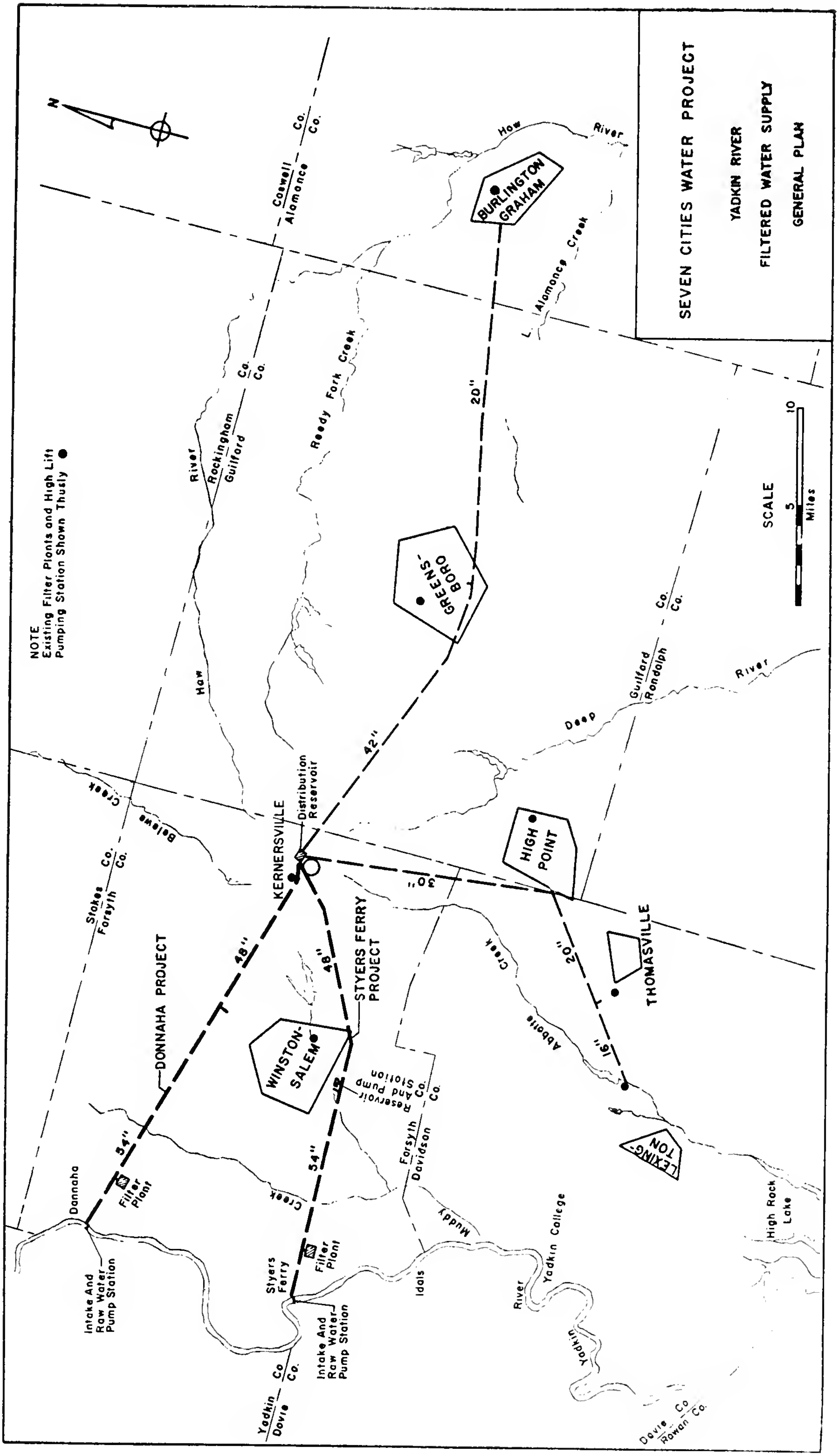
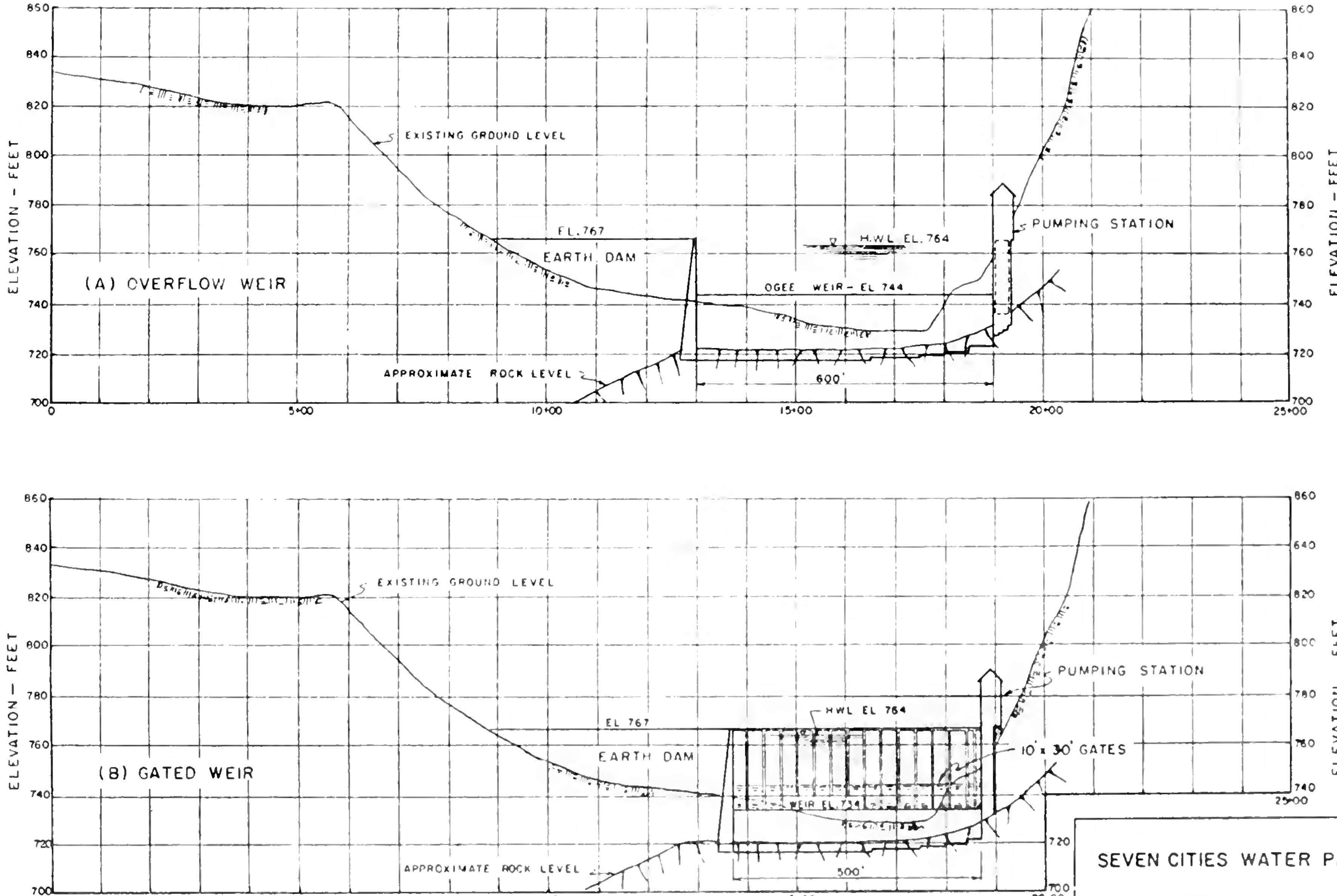

SEVEN CITIES WATER PROJECT
YADKIN RIVER
FILTERED WATER SUPPLY
GENERAL PLAN
NOTE
Existing Filter Plants and High Lift Pumping Station Shown Thusly
SCALE
5
10
Miles
N
BURLINGTON GRAHAM
GREENS-BORO
HIGH POINT
THOMASVILLE
LEXING-TON
WINSTON-SALEM
KERNERSVILLE
Distribution Reservoir
DONNAHA PROJECT
STYERS FERRY PROJECT
Reservoir And Pump Station
Donnaha
Intake And Raw Water Pump Station
Filter Plant
Styers Ferry
Filter Plant
Intake And Raw Water Pump Station
20"
42"
30"
48"
48"
54"
54"
20"
16"
Caswell Co.
Alamance Co.
Rockingham Co.
Guilford Co.
Stokes Co.
Forsyth Co.
Forsyth Co.
Davidson Co.
Guilford Co.
Randolph Co.
Yadkin Co.
Davie Co.
Davie Co.
Rowan Co.
Haw River
Haw
River
Reedy Fork Creek
L. Alamance Creek
Belews Creek
Deep River
Abbotts Creek
Muddy Creek
Yadkin River
Yadkin
Yadkin College
Idols
High Rock Lake

EXHIBIT 10

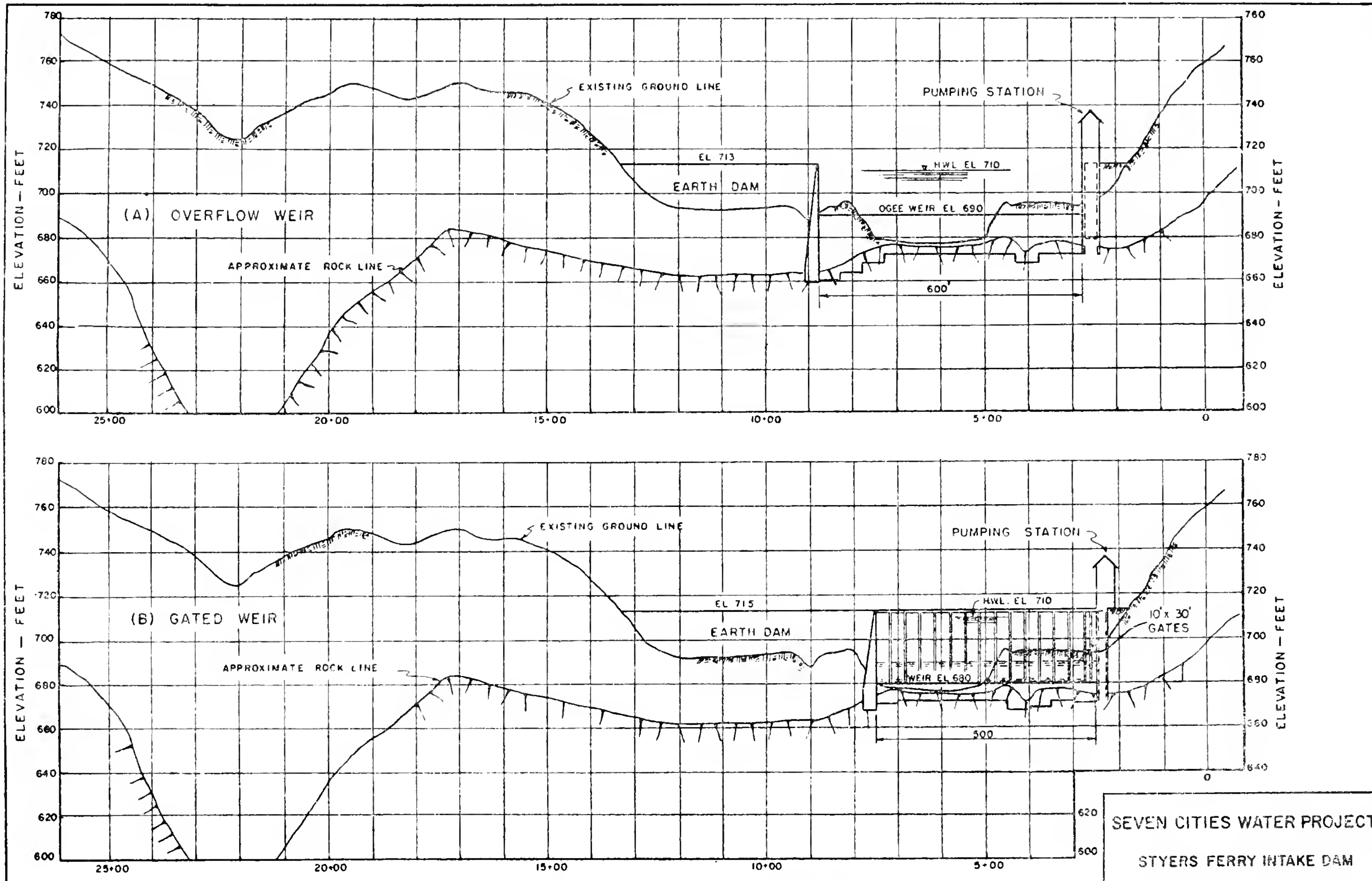


PROFILES THOUGH CENTER LINE OF DAM LOOKING UPSTREAM

SEVEN CITIES WATER PROJECT

DONNAHA INTAKE DAM

AND PUMPING STATION



PROFILES THROUGH CENTER LINE OF DAM LOOKING UPSTREAM

SEVEN CITIES WATER PROJECT

STYERS FERRY INTAKE DAM AND PUMPING STATION

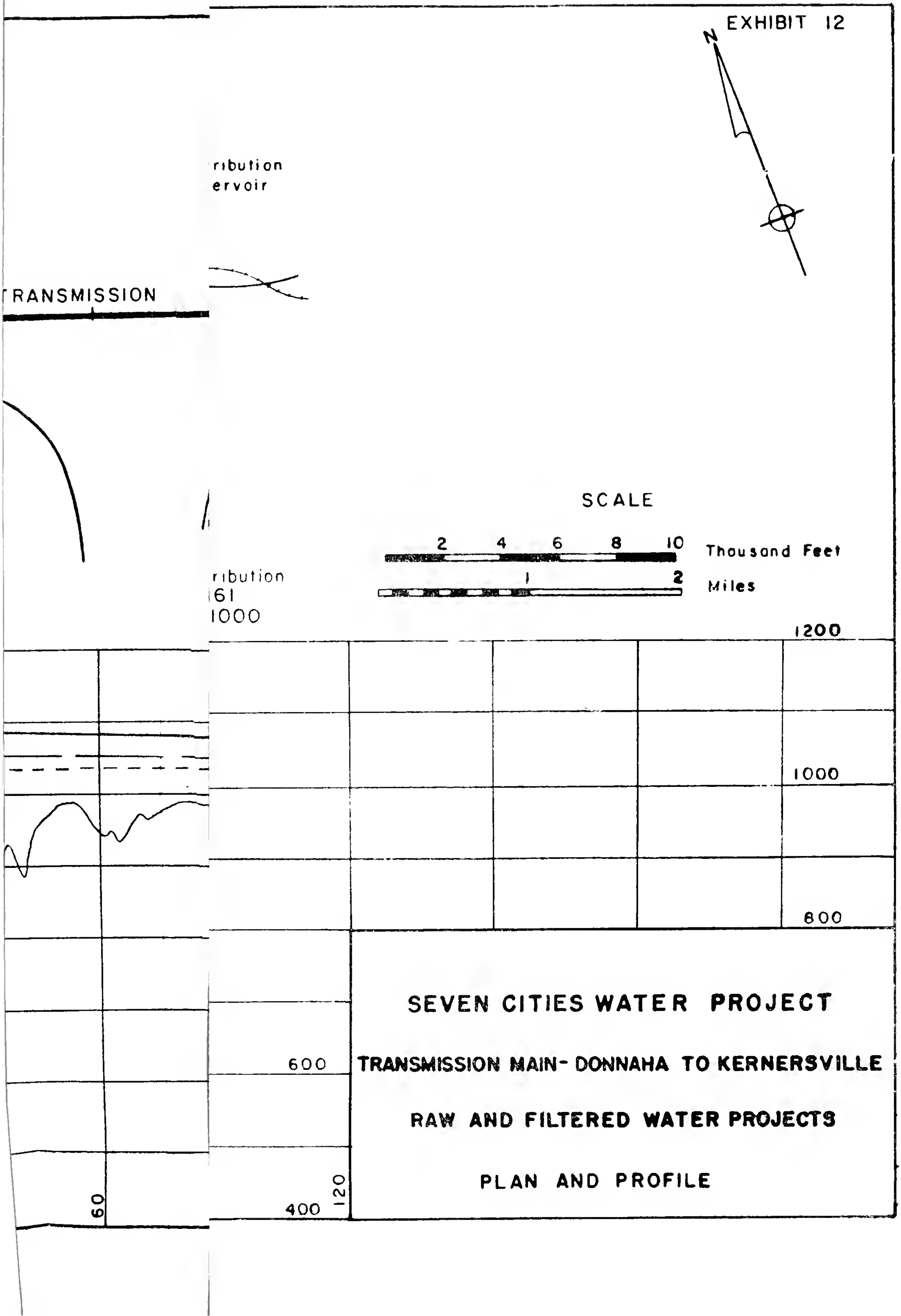
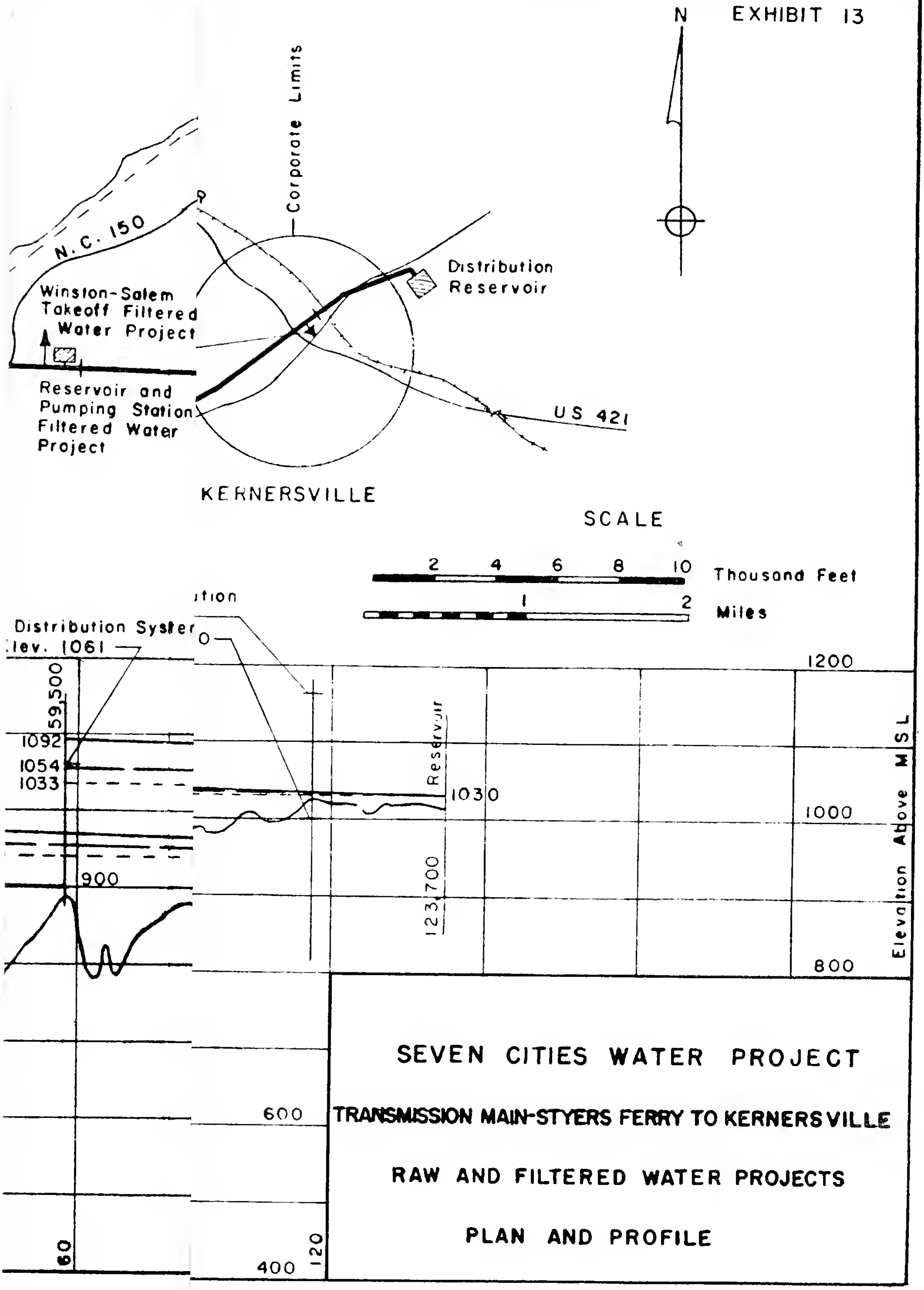


EXHIBIT 12
N
ribution
ervoir
TRANSMISSION
SCALE
2 4 6 8 10
Thousand Feet
1 2
Miles
ribution
161
1000
1200
1000
800
600
400
60
120
SEVEN CITIES WATER PROJECT
TRANSMISSION MAIN - DONNAHA TO KERNERSVILLE
RAW AND FILTERED WATER PROJECTS
PLAN AND PROFILE

EXHIBIT 13

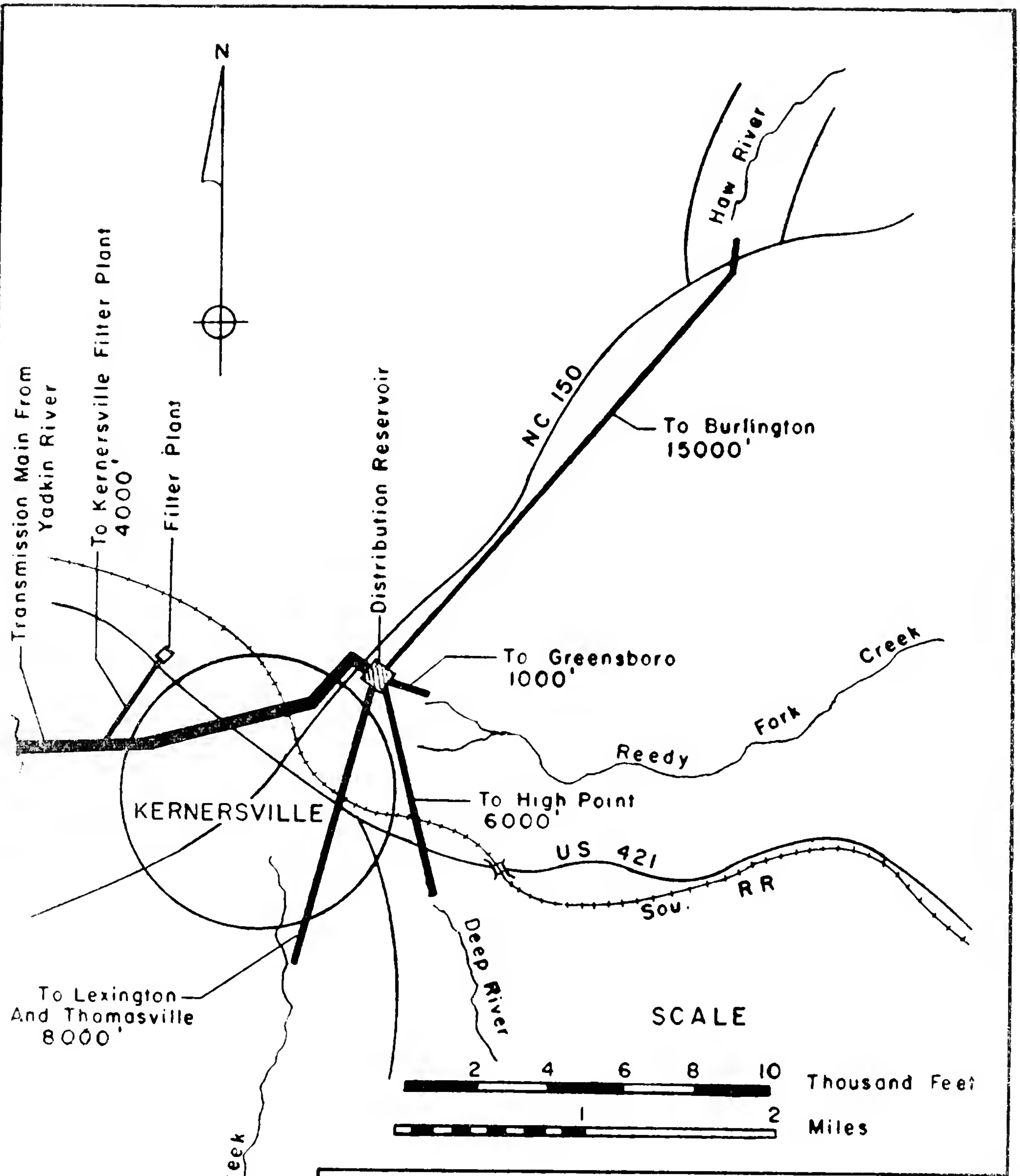


SEVEN CITIES WATER PROJECT

TRANSMISSION MAIN-STYERS FERRY TO KERNERSVILLE

RAW AND FILTERED WATER PROJECTS

PLAN AND PROFILE



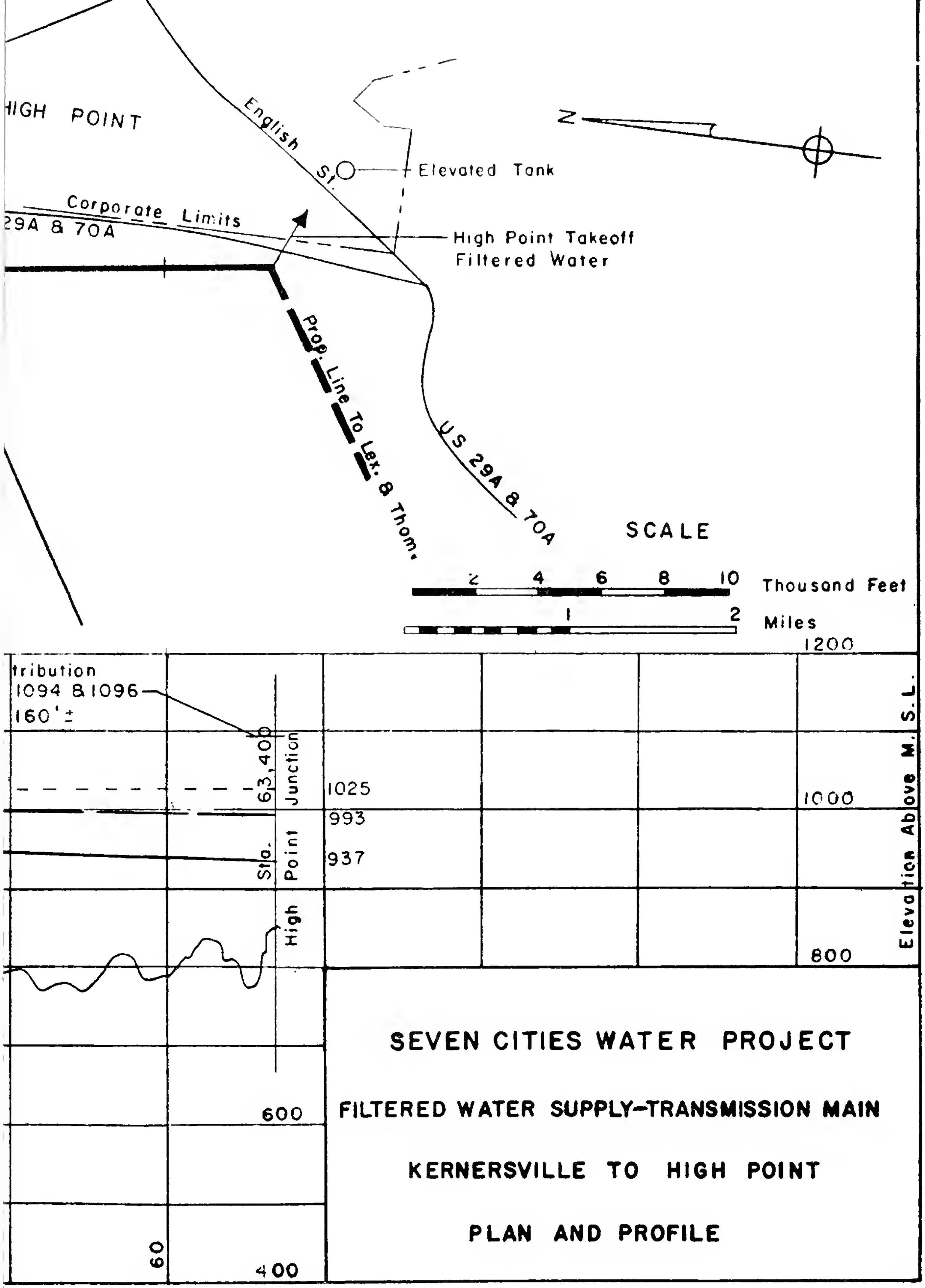
SEVEN CITIES WATER PROJECT

RAW WATER SUPPLY

DISTRIBUTION MAINS AT KERNERSVILLE


50

EXHIBIT 17



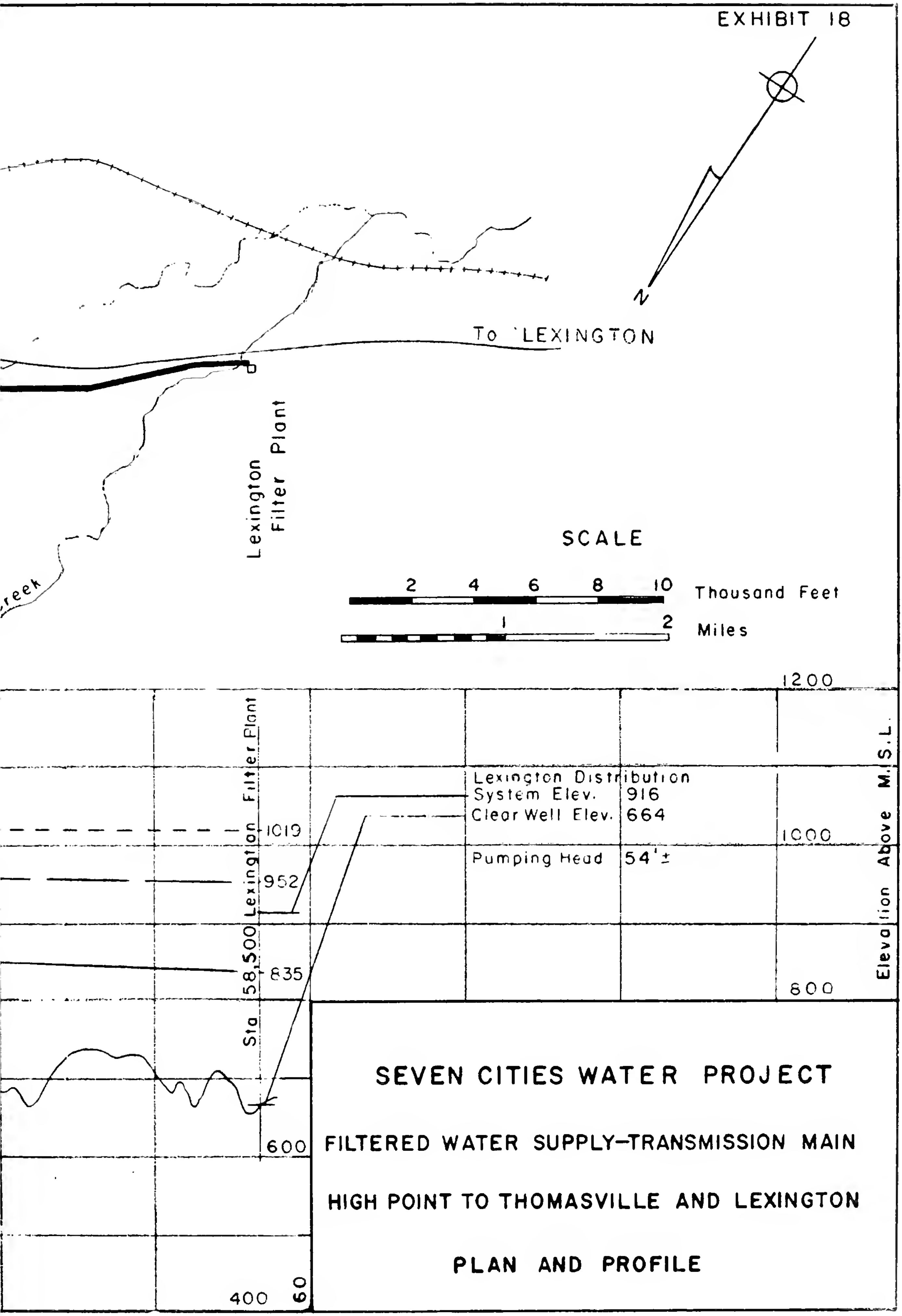
SEVEN CITIES WATER PROJECT

FILTERED WATER SUPPLY–TRANSMISSION MAIN

KERNERSVILLE TO HIGH POINT

PLAN AND PROFILE

EXHIBIT 18



SEVEN CITIES WATER PROJECT

FILTERED WATER SUPPLY—TRANSMISSION MAIN

HIGH POINT TO THOMASVILLE AND LEXINGTON

PLAN AND PROFILE